REDUCING FISHING VESSEL CAPSIZING IN NEWFOUNDLAND AND LABRADOR BY ESTABLISHING A RELATIONSHIP BETWEEN COMMON CAUSES AND OPERATORS' UNDERSTANDING OF STABILITY AND RISK

By Bryan Davis

A thesis submitted to the School of Graduate Studies in partial fulfillment of the requirements for the degree of Master of Engineering

Faculty of Engineering and Applied Science

Memorial University

May 2019

St. John's Newfoundland and Labrador Canada

Abstract

Commercial fishing is considered one of the most dangerous industries in the world. Among the different types of fishing vessel accidents, capsizing has one of the highest fatality rates. In Newfoundland and Labrador, fatalities, due to the loss of stability in fishing vessels, have been identified as a significant problem.

This study's primary objective was to determine the main causes of fishing vessel capsizing and recommend preventative measures to reduce the frequency of fishing vessel capsizes in Newfoundland and Labrador. Through an analysis of fishing vessel capsizing investigation reports, and a series of discussions with operators, the study identified the primary causes of these events. In 57 of the 60 capsizes analyzed, operators' actions were determined to play a significant role.

A second component of the discussion portion of the study focused on operator and crew understanding of vessel stability. This portion of the study revealed a correlation between the amount of formal training an operator had received and their understanding of stability. Those who had received some form of stability education appeared better equipped to avoid or manage potential capsizing events.

Many fishing vessel capsize events were attributed to operator error and operators with no stability training are more likely to make poor decisions based on common misconceptions of vessel stability. Based on this conclusion, it is recommended that a compulsory stability education course be offered in the province. An outline and proposed curriculum including potential delivery methods for such a course is presented.

Acknowledgments

Thanks to Memorial University, SafetyNet Centre for Occupational Health and Safety Research, Mitacs, Newfoundland and Labrador Fish Harvesting Safety Association, and the Ocean Frontier Institute for monetary support for the study.

I have many people to thank who made this project possible. First, a big thank you to Mark Dolomount at the NLFHSA. Not only did you have some great recommendations, but you were consistently available to address my (many) requests. I would also like to thank Dr. Barbara Neis and Angela Drake of SafetyNet for their continued support and insight throughout the project. Thank you all for taking the time.

I realize every graduate student probably acknowledges their supervisors, but I truly feel that Dr. Bruce Colbourne and Dr. David Molyneux went above and beyond. Thank you both for your guidance and support and ensuring that the project did not fly off the rails. Any future graduate students will be lucky to have you as their supervisors.

I cannot thank my family enough for their continued support over the last few years. From deciding to quit my job and move to Japan, to returning home to start my Masters (and live rent free), you guys were always there. Mom, Dad, and Sarah, thanks for everything.

Finally, thank you to the 31 operators who agreed to meet with me during this study. On conditions of anonymity, I am not able to mention any names, but you know who you are. I cannot imagine this project without your input. If you are reading this, I hope you realize just how much I truly appreciate your contributions.

Table of Contents

List of Figures

List of Tables

1.0 Introduction

1.1 Background and Objectives

Commercial fishing has been vital to the economy of Newfoundland and Labrador for hundreds of years. Despite a moratorium, imposed in 1992 to preserve cod stocks, fishing for other species has remained a major industrial activity in the province. As of 2016, commercial fishing directly accounted for 3,100 jobs in the province and an additional 3,000 indirect jobs (Newfoundland and Labrador Statistics Agency, 2017). Not only does fishing provide a significant source of employment in NL, it is a fundamental part of the province's culture and identity.

High profile fishing vessel accidents in Newfoundland and Labrador have led to public pressure to address fishing safety, frequently with emphasis on systematic issues such as vessel design or search and rescue response. Incidents such as the *Ryan's Commander* (Richer, S., 2007) and the *Melina and Keith II* ("Melina and Keith II Sinking Report," 2007) in recent years have led to calls for improvements to working conditions and regulations in the commercial fishing industry.

The overall objective of this study is to identify methods to reduce the frequency of fishing vessel capsizing through appropriate preventative measures. Before effective preventative measures can be put in place, the primary contributing causes of fishing vessel capsizing must be determined. Without an understanding as to why fishing vessels capsize, it is unlikely that preventative measures will be successful.

To assess contributing factors, publicly available marine incident reports were analysed in order to identify common causes of specific cases of fishing vessel capsizing. A further investigation of near miss reporting, a technique used in other industries to guide safety decisions and provide additional data, was conducted. This information was gathered through interviews and discussions with fish harvesters to determine the incidence and causes of near miss capsizing events and to further assess their understanding of vessel stability and how they perceive the risk of capsizing. These discussions followed one of two formats: a one-on-one interview or a roundtable discussion with multiple participants.

Understanding operators' stability knowledge and their concern for capsizing is an important element of this project's research. The literature review (section 2.0) shows that multiple authors have studied the link between fishing vessel operators' understanding of stability and the likelihood of a vessel's loss of stability. Conducting interviews and roundtable discussions with operators allowed for an assessment of the general understanding of basic principles of stability and the perception of risk among operators in Newfoundland and Labrador. From these conversations, the connection was established between operators' knowledge and common causes of capsizing identified from investigation reports. The link between these two parameters is important for putting effective preventative measures in place to reduce capsizing.

Once primary causes of capsizing are identified and operators' level of stability knowledge is understood, more effective measures can be taken to mitigate capsizing events. Identifying and correcting operators' practices and decisions that have detrimental effects on stability may be a more efficient way to reduce capsizing incidence. Better understanding the link between operator and crew knowledge of stability and the incidence of stability accidents is thought to be a promising approach in preventing stability accidents. This study's hypothesis is that an operator's actions or decisions that contribute to fishing vessel capsizing are due, in part, to a lack of education or training in vessel stability. Operators' decisions related to vessel stability may be based on misconceptions arising from lack of awareness and understanding of basic stability principles or a lack of knowledge of the consequences of detrimental stability actions.

After considering both operators' understanding of vessel stability and common causes of capsizing, a program that educates operators and provides them with better stability knowledge and training can be recommended. It is important that before implementing any type of educational program, the needs of the operators be considered. Without considering the current level of stability knowledge of operators, it is unlikely that a program will be successful in making a significant reduction to vessel capsizes. The interviews and roundtables conducted as part of this study were used as a qualitative assessment of operators' understanding of stability. With this information, a program can be tailored to individuals who may have little or no formal education. This knowledge and training will allow operators to make better informed decisions during fishing operations to mitigate the risk of capsizing.

1.2 Outline of Thesis

This thesis begins with a literature review (section 2.0) of research relevant to the prevention of fishing vessel capsizes. Included in this portion of the thesis is a review of general fishing vessel stability research, dynamic stability, the use of near miss reporting in other industries, fishing vessel stability education programs, and current regulations related to fishing vessel stability. Gaps in the current academic research and regulations were identified. Section 3.0 discusses certification requirements relevant to the research. This section includes current stability training requirements and restrictions on the length of inshore fishing vessels.

Section 4.0 highlights the research methodology for both the analysis of the investigation reports and discussions with operators. The results for both portions of the research are presented in section 5.0. For the investigation reports, quantitative results are presented, with the reported contributing causes from each incident discussed and tabulated. For interviews with operators, the results are qualitative. The conclusions from these discussions in regards to fishing vessel stability and the perception of the risk of capsizing are identified and discussed. Section 5.0 concludes with a discussion of near miss capsizing events that were obtained from interviews and roundtables. These results supplemented the quantitative data from the analysis of investigation reports.

The results of the research are analyzed and discussed in section 6.0. The primary causes of capsizes as identified from investigation reports are examined. Each cause was identified as being due to poor decisions by operators, or to circumstances created by poor decisions. These can be linked, at least in part, to a lack of understanding of stability on behalf of owners and/or operators. This section includes a statistical analysis of fishing vessel capsizing trends in Canada. A possible correlation between the trend and operator training in Canada is discussed.

Section 6.0 continues with a discussion of the qualitative data obtained from interviews and roundtable discussions with operators. The primary conclusion from these discussions was the positive correlation between an operator’s understanding of stability and the amount of stability training that operator had received.

Recommendations for additional work are presented in section 7.0. The primary recommendation from this research was the need for improved stability awareness among members of the Newfoundland and Labrador’s fishing community. Finally, an outline for an educational program to improve stability awareness in Newfoundland and Labrador is discussed in section 8.0.

2.0 Literature Review

This review covers the current literature related to fishing vessel stability including:

- General analysis of fishing vessel stability
- Research to reduce the frequency of fishing vessel capsizing
- Limitations of stability regulations due to a lack of dynamic stability considerations
- The impact near miss reporting has had on accident reduction in other industries
- Impact of operator training on vessel stability
- Stability education programs aimed at improving operator awareness

These are discussed in relation to future work to reduce capsizes and work associated with this research.

2.1 General Fishing Stability Research

Fishing vessel capsizing is a serious event that often results in fatalities and significant economic loss. Capsizing is a result of a vessel becoming unstable and overturning in the water. Research has been done to identify the primary causes of a vessel becoming unstable and the factors that can have an adverse effect on a vessel's stability. This thesis will focus on links between operator decisions and stability outcomes with emphasis on operations in Newfoundland and Labrador.

It is well understood that commercial fishing is a high-risk industry. Roberts (2002) investigated industries in the UK and identified commercial fishing as the country's most dangerous occupation. The fatal accident rate of 103.1 deaths per 100,000 worker-years is approximately twice as high as next most dangerous industry (merchant seafaring) and 50 times higher than for the average worker. While there are many different types of accidents that affect fishing vessels, capsizing has been found as the highest contributor to the number of fatalities (Loughran et al., 2002).

Capsizing, compared to other accidents, is relatively rare. Loughran et al. point out that capsizing accounted for only 2% of all fishing vessel incidents recorded in the United States between 1989 and 1995. However, during the same period, capsizing accounted for 29.1% of all deaths. While capsizing events are infrequent, they are of great concern because of the high fatality rate. Capsizing is often a precipitous event, which leaves crews with little or no warning prior to an incident. In addition, capsizing usually results in rapid flooding or sinking which immediately forces evacuees into the water, frequently without time to deploy safety equipment. These factors contribute to the high fatality rates.

Current stability regulations for fishing vessels are based on static stability measurements, but it is well understood that capsizing is most often the result of dynamic forces on a vessel (Gourlay and Lilienthal, 2002). While a lack of regulation concerning fishing vessel stability may be a problem, imposing stricter regulations, using existing criteria, is not seen by some authors as an effective solution to reduce capsizing (Johnson and Womack, 2001).

2.2 Reducing Fishing Vessel Capsizing

2.2.1 Model Testing to Determine Causes and Reduce Capsizing

Researchers have aimed to identify the primary causes of fishing vessel capsize through the use of model tests. Perez Rojas et al. (2007) investigated two incidents off the coast of Spain. Scaled models of each vessel were evaluated in sea states similar to those encountered at the time of capsizing. The authors note that they were only able to get one of the vessels to capsize during the tests, and that was when the wave length and height were varied such that the waves were overly steep. The authors concluded that the capsizing likely occurred because the vessel's stability was reduced due to operators' actions.

Taguchi et al. (2013) undertook a similar procedure to ascertain the cause of two vessels capsizing near Japan: one in the North Pacific Ocean and the other in the East China Sea. Once again, scaled model tests were performed and analyzed to determine why the ships capsized. The authors were able to identify multiple reasons for the capsizing of each vessel, highlighting the complicated nature of the accidents.

2.2.2 Development of Technology to Assist Operators

Gonzalez et al. (2012) discuss the high-risk of capsizing for smaller fishing vessels. They explain that the high-risk is largely due to a lack of training of small fishing vessel crews. In many cases, crews have a poor understanding of stability and do not understand the level of risk associated with their job. The paper also points out that stability books are ineffective in preventing capsizing because they are not well understood by operators. The authors explain that there is also a lack of regulations guiding fishing vessels in many parts of the world.

In order to reduce capsizing, the authors developed stability software that could be implemented on most vessels. They focused on ensuring that the software was "user friendly." After development, the authors tested the software with a "usability analysis." This analysis involved operators using the software and their performance was measured in the areas of efficiency, accuracy, learnability, and emotional response.

Gonzalez et al. (2016) also approached the task of reducing fishing vessel capsizing by developing an on board system to compute a vessel's metacentric height (GM) in real time. The system used inputs from the crew to generate a vessel's initial stability. While this system has benefits, uncertainty exists because there is no way to determine how accurate the crew's inputs are. The most likely source of error, as identified by the authors, is determination of a vessel's transverse radius of gyrations by the crew. This becomes important when estimating the GM based on vessel motion frequencies.

2.3 Dynamic Stability

An important consideration for this project is the current regulatory requirements for fishing vessel stability. Current Transport Canada regulations include requirements for initial and large angle stability for larger fishing vessels, but do not cover the Canadian Small Fishing Vessel Class (Transportation Safety Board of Canada, 2006). Initial stability is determined by performing an inclining experiment to calculate a vessel's metacentric height (GM), while loading and large angle stability is presented via stability booklets. Stability booklets show GZ curves for various loading conditions. GZ curves are a means to predict the maximum angle to which a vessel can roll before capsizing (Transport Canada, 2017). In addition, the GZ curve provides a measure of the energy that a rolling vessel can absorb in a dynamic situation.

GM and GZ curves have limitations in assessing a vessel's stability because they do not fully account for dynamic effects, particularly the effects of different wave frequencies. As discussed by Molyneux (2007), research into stability in waves is the focus of much research in the ship stability community. However, current stability regulations employ empirical methods to account for dynamics. Ship dynamics is a relatively well understood field in which ship motions from waves are predicted using Newton's Second Law of Motion (Gourlay and Lilienthal, 2002). Gourlay and Lilienthal recognize problems associated with stability regulations based on static measurements. They explain that while capsizing is an event that arises from a vessel's dynamic behaviour, GZ curves are static indices. As such, they do not account for effects such as ship speed and heading or wave parameters (i.e. height, steepness, and frequency). This discrepancy can lead to a false sense of security among operators. If a vessel is found to have sufficient static stability as required by regulations, operators may be prone to underestimate the risk of capsize due to dynamic loads and motions.

Johnson and Grochowalski (2002) also recognize that vessels often capsize as the result of dynamic action. They performed model tests in a range of wave heights and periods and observed the vessel response. They conclude that building on their work could lead to the development of risk based stability criteria as opposed to the deterministic criteria for static stability currently in place.

Gourlay and Lilienthal's (2002) and Johnson and Grochowalski's (2002) research points out that static stability regulations do not fully account for the dynamic effects, such as broaching, that often lead to capsizing.

2.4 Near Misses

One of the project objectives in the current study is to try to document near miss accidents in the commercial fishing industry as a means of expanding the data on common causes of capsizing. The practice of reporting near misses is virtually non-existent in the fishing industry, which is in contrast to industries such as oil and gas, mining, and manufacturing. In many industries, it is common practice to report near misses in order to learn from them and avoid more serious, major accidents. Because this practice has not been adopted by the commercial fishing industry, near miss incidents cannot currently be used to supplement (reported) major accidents to create a safer working environment. The benefit of using near miss data is summarized by Wright and van der Schaff (2004).

> Decision making about investing in safety improvements is usually based upon the relative importance of root causes in accidents and failures. However, such decisions can only be reached by referring to statistics from large databases. As accidents themselves are (fortunately) too few in number to aid such decision making processes the use of near misses to dramatically increase the number of databases is one way to counteract this problem. (p.105)

Jones et al. (1999) looked at the chemical industry and discussed the importance of reporting near misses. The authors argue that because near misses serve as warnings of a major accident occurring, a system that reports and investigates near misses can be an effective prevention tool.

Numerous statistics are available that relate the number of full scale accidents to the number of near misses but the ratios between the two variables vary. Jones et al. list these and point out that while there may be some variance, it is accepted that for a single major accident, there is a larger corresponding number of smaller accidents and near misses. There is a proportional relationship between near misses and major accidents: as the number of near misses is reduced, so is the number of major accidents. If reported near misses serve as lessons learned, their frequency will decrease. In turn, so will major accidents.

Jones et al. also stress the importance of the difference in reported near misses and unreported near misses. They discuss that many workers are reluctant to report near misses for fear of retribution from their employer. Companies that have stressed the importance of reporting near misses and ensured that employees will not face discipline for reporting them have seen accidents reduced. There is an inversely proportional relationship between reported near misses and major accidents. This is perhaps the most important takeaway from the Jones et al. paper as it relates to commercial fishing: documenting and reporting near misses can reduce the frequency of major accidents. Therefore, it is hypothesized that if capsizing near misses are documented, they can be an effective tool in implementing safe practices to reduce the frequency of capsizing.

Nielsen et al. (2006) investigated the effect that reporting near misses had on the frequency of lost time incidents (LTIs) and major accidents. For the study, they set up a near miss reporting system in two different manufacturing plants. Prior to the experiment, neither plant had a system in place to report near misses. The experiment spanned three years and results were collected for one-and-a-half-years with no reporting system in place and one-and-a-half-years with the system in place. The authors based the experiment on Heinrich's work (1950) that states that there exists a large ratio of near misses to LTIs and that the causes of LTIs and near misses are the same. The authors hypothesize that reporting and learning from near miss incidents can reduce LTIs because it allows management to put proper preventative measures in place.

Both plants had near miss reporting systems put in place at the mid-point of the study. Plant A, which consisted of a younger demographic of workers, used the system effectively. In the first year and a half of the study, no near misses were reported. When the system was put in place at the one-and-a-half-year mark, 1883 near misses were reported until the study ended. The authors also explain that top management at the plant actively encouraged all employees to report any near misses.

Plant B, which had a higher employee average age than plant A, failed to use the near miss reporting system that was put in place. There were no near misses reported during the full duration of the study. The authors point out that there was little engagement from management to use the reporting system. In the study, a "safety climate" was quantified to describe each plant's dedication to a safe work environment. This parameter takes into account reporting of near misses and LTIs. Plant A had a much higher safety climate score than Plant B.

Plant A, which had made effective use of the reporting system, saw LTIs drop significantly over the three-year study (44% reduction was observed). Plant B, which failed to report near misses, did not see a significant change in LTIs (17% reduction which was in line with historical fluctuations). The study was effective in confirming the authors' original hypothesis that reporting near misses can reduce LTIs because it allows for preventative measures to be taken. The study identifies management commitment as the most important contributor to reporting near misses. They further stress that anonymity is important because near misses due to unsafe behaviour are more likely to be reported if sources are able to remain anonymous. Finally, Heinrich's high ratio of near misses to LTIs was observed as Plant A had a final count of 1883 near misses to 14 LTIs.

Wright and van der Schaaf (2004) studied an important hypothesis, often stated in near miss studies, that near misses and LTIs have identical causes. This is referred to as the "causal hypothesis." The hypothesis was an original part of Heinrich's work but, as the authors explain, it has been challenged in more recent studies. The hypothesis is an important factor in determining the effectiveness of reducing LTIs by reporting near miss incidents.

The study focused on a literature review of papers that investigate the relationship between the cause of near misses and LTIs. For the numerous papers reviewed, those that challenged the causal hypothesis were each found to have flaws in their original assumptions that led to inaccurate conclusions. The study found that Heinrich's causal hypothesis is still accurate and validates the use of near misses to reduce LTIs. The authors also studied incidents in the UK railroad industry and found 198 near misses and 17 fatalities. This supports the idea that there are a large number of near misses for every fatality.

2.5 Operator Training's Impact on Vessel Stability

Womack (2002) examined the current stability criteria for small fishing vessels and made a general assessment of crews' understanding of stability. The paper suggested that there are multiple factors that lead to vessels becoming unstable during operations. These factors include a lack of understanding of stability by crews, insufficient presentation of stability guidance from naval architects and engineers, and insufficient stability criteria.

A crew's understanding of stability and the presentation of stability data are not independent. As Womack explains, stability data is in the form of either a stability book or stability letter. Both are often incomprehensible to the operators of fishing vessels. Vessel stability is a technical field and letters and books are composed by naval architects and engineers with years of technical training. The disconnect between engineers and operators is significant and operators often do not trust the assessment of engineers and do not understand the stability work performed. The lack of understanding can lead to decisions that contribute to a loss of vessel stability.

Womack identifies the solution to this problem in two parts: first, engineers must keep in mind the technical knowledge of operators and produce stability letters that are "comprehensible by crews with little or no technical training." Womack suggests that simplified, color coded load matrices which outline different loading scenarios and weather conditions as a possible solution to this. Second, Womack explains that educational programs on vessel stability for operators are crucial to the success of any published data engineers produce, however simply presented it may be. Training that discusses the basic concepts of stability is required to bridge the gap between operators and engineers and it is an important step in ensuring that operators trust the stability work produced by naval architects. Operators equipped with the basic knowledge of stability that includes an understanding of the important relationship between a vessel's center of gravity and center of buoyancy will be in a position to make more informed decisions while operating their vessels.

Womack also cites insufficient stability criteria as a concern. He traces the origins of current stability criteria in place for fishing vessels and argues that these are out-dated and not reflective of current vessels. Because the current criteria are static and do not account for scalability, they do not capture many of the problems that lead to capsizing. Further, for European fleets of vessels less than 24m in length (79 feet), Womack proposes there are currently "…no universally accepted stability evaluation methods available".

Womack's 2002 paper builds on a paper written by Johnson and Womack (2001) that discusses the best way to develop a "user friendly approach to fishing vessel stability." The paper outlines a panel put in place by the Society of Naval Architects and Marine Engineers (SNAME) to improve the safety culture of fishing vessels in regards to stability. The panel comprised of four groups (A, B, C, and D) with group B focusing on developing tools to allow seafarers to better understand stability.

Johnson and Womack (2001) state that the primary defence against capsizing is a truncated version of a stability book, the stability letter. Group B's work is motivated by the fact that stability books are ineffective because they are not understood by the crew. The authors point out two reasons for this, both of which describe a disconnect between naval architects and fishing vessel operators. The first is that terms used by naval architects to describe the stability of a vessel are often incomprehensible to crews with no formal stability training. The second is that stability letters include restrictions that are impractical and measured in ways that are dangerous or impossible for the crew to determine. The authors use the example of specifying minimum freeboard to illustrate. As put by the authors: "While a good method in theory is to specify maximum loadings, it is impracticable, and dangerous, for a crew to measure freeboards while underway by hanging over the boat's side in any type of sea." Stability letter specifications such as this often result in the letters being ignored by members of the crew.

The paper discusses the problems posed by crews having little or no stability training. Specifically, they identify a lack of understanding of the difference between initial (small angle) and overall (large angle) stability as a serious problem. Crews most often experience a vessel's initial stability in everyday operations but typically only deal with overall stability during a rare, severe weather incident. In many cases, vessels are loaded to improve the "feel" of the vessel at small roll angles, which is often interpreted as improved stability. This is commonly done by ballasting or overloading the vessel. Crews do this unaware that their actions are reducing the overall stability; the range of positive righting arms, area under the righting arm curve, and the heel angle of maximum righting moment all see significant reductions when the vessel is loaded to reduce the initial stability (or stiffness of the vessel). As a result, the overall stability may be insufficient when the weather becomes bad and the vessel experiences large angle roll motions.

Johnson and Womack propose that load matrices are good way to mitigate the risk of capsize. They are presented as easy to use for operators with no formal training and have a simple layout. The inputs to the example load matrix they show are the level of ballast and the number of cages on the vessel. The outputs are the conditions which the vessel can safely operate in given the inputs (i.e. for 10 cages with 75% full fuel tanks the vessel can safely operate in storms - see Figure 1). The matrices, the authors believe, would be an improvement over stability letters and the crew would not have to rely on the "feel" of the vessel to estimate the vessel's stability. An important consideration of the load matrix method is that the captain has the ability to make operational decisions because they would better understand how the matrix applied to the vessel. This is in contrast to stability letters, which often put operational decisions in the hands of the naval architects.

F/V FISHING BOAT – STABILITY LOADING MATRIX								
		MAXIMUM CAGES IN HOLD – DREDGE FULL & ON RAMP						
PORT & STBD FUEL TANKS	POTABLE WATER	0 CAGES	10 CAGES	20 CAGES	30 CAGES	40 CAGES	50 CAGES	60 CAGES
100%	100%	SAFE	SAFE	UNSAFE	UNSAFE	UNSAFE	UNSAFE	UNSAFE
75%	100%	SAFE	SAFE	UNSAFE	UNSAFE	UNSAFE	UNSAFE	UNSAFE
75%	75%	SAFE	SAFE	SAFE	UNSAFE	UNSAFE	UNSAFE	UNSAFE
50%	75%	SAFE	SAFE	SAFE	UNSAFE	UNSAFE	UNSAFE	UNSAFE
50%	50%	SAFE	SAFE	SAFE	SAFE	UNSAFE	UNSAFE	UNSAFE
50%	25%	UNSAFE	SAFE	SAFE	SAFE	UNSAFE	UNSAFE	UNSAFE
25%	50%	UNSAFE	SAFE	SAFE	SAFE	SAFE	UNSAFE	UNSAFE
25%	25%	UNSAFE	UNSAFE	SAFE	SAFE	SAFE	SAFE	UNSAFE
10%	10%	UNSAFE	UNSAFE	UNSAFE	SAFE	SAFE	SAFE	UNSAFE

Figure 1: Load Matrix from Johnson and Womack (2001)

In order for the load matrix, or any other replacement for stability letters, to be effective, Johnson and Womack argue some formal training is required. They propose a program consisting of a written manual and verbal presentation that would teach crews the basic concepts of vessel stability. An aspect of the course in the paper's previous sections aimed to "show the effect on a boat's stability level from typical boat operations." Included in this was the effect that operators' decisions had on a vessel's stability, such as loading conditions and free surface effect.

Johnson and Womack address some of the major problems regarding vessel stability and how it is influenced by crews' actions. They identify the knowledge gap between naval architects and vessel operators as a problem. Their proposed solution to bridging the gap involves improving stability guidelines and introducing training that takes into account operator's knowledge and background. They recognize the need for naval architects and operators to work together to improve the safety culture on fishing vessels.

Howe and Johansen (2007) developed a fishing vessel stability education program called "Fish Safe Stability Education Program" (FSSEP). The authors discuss the risk of capsize and fatalities that typically occur. With each incident, the authors explain, there is a discussion about why fishers struggle with the concept of stability. It is the perilous nature of capsizing and fishers' lack of understanding of stability that was the motivation behind the creation of the FSSEP in 2005.

The program focuses on applying the fundamentals of adult training and education to fishers and stability. While stability training was in place, it lacked effectiveness because it did not fully appreciate the "complex problem that involves the inter-relationship between fishers, traditional training methods, and the learning environment." The adult education program that the authors devised was aimed at addressing this problem more thoroughly than previous work had.

The authors state that it is imperative that program instructors have not only some formal teaching training but also fishing experience. The program first gives a needs assessment, which refers to an industry meeting. At the meeting, fishers made it clear that they favoured an educational program because it was the only way any regulations could be implemented. Next, the learning outcomes of the FSSEP were listed as "You will take ownership of fundamental principles of stability, and they will be central to your everyday reality when making any decision that affects your vessel's operation". The program used both direct instruction (i.e. lectures) and indirect instruction (i.e. laboratories, case studies) to meet the learning outcomes. Further, discussions and video were important to accommodate participants who could not read or write. Specifically, the four curriculum goals were:

1. You will have a stability vocabulary that will enable you to talk about stability with personal authority
2. You will be able to read a stability data book and use the information to help make operational decisions when fishing
3. You will appreciate the cumulative nature of threats to vessel stability
4. You will be able to write stability instructions specific to your fishing vessel and fishing operations

Following the course, participants were surveyed to assess the program's effectiveness. Comments were considered and improvements were made to the program as required. Comments from participants were generally positive. Many believed that they came away with a much better understanding of stability and recognized some of the error in their previous way of thinking. The results show an effective education program can bridge the gap between naval architects and operators. The paper does not assess whether capsizing in British Columbia (BC) has decreased as a result of the program. For greater detail on the FSSEP, refer to section 2.6.

Kaplan and Kite-Powell (2000) conducted interviews with 22 members of the New Bedford (USA) fishing community to gauge the level of satisfaction of the government's safety regulations with which they had to comply. The study did not focus on capsizing and all incidents were of equal interest to the authors. The study is important because one of the primary findings was that fishers felt there was a large disconnect between government officials who were responsible for regulations and the operators who had to abide by them. There was a strong consensus among those interviewed that they had no opportunity to provide input into the regulations. They felt that those responsible had little understanding of the industry's hands on operations and, as a result, the regulations did little to create a safe working environment.

Wang et al. (2005) analyzed fishing vessel accidents in the UK from 1992 to 1999. Their study points out that imposing stricter safety regulations does not always reduce the number of vessels lost. The paper cites rule changes in the UK in the mid-1980s in which stricter regulations were applied to vessels 12m and over. While this resulted in reduced losses of larger vessels, losses of vessels, less than 12m, doubled. The authors attribute this to the number of registered vessels less than 12m long doubling during the same time period; operators simply avoided the regulations by using vessels smaller than those to which the new rules applied.

The Wang et al. (2005) paper goes on to state that 20.72% of the accidents analyzed could be attributed to "negligence/carelessness of the crew." A problem identified by the authors is that for many accidents there is not enough information to determine the primary causes. Finally, the authors conclude the paper by emphasizing the need for an enhanced safety culture in the fishing community.

Loughran et al. (2002) discusses how disasters have led many to question the current level of risk in the industry and how it may be reduced. The paper highlights the work of previous authors that focused on improving training programs to reduce accidents. The paper does not just focus on capsizing but all types of accidents to fishing vessels. It does highlight the fact that capsizing is a relatively rare event that has high consequences. From 1989 to 1994 in the UK, capsizing ranged from 1% to 6% of all accidents annually. However, capsizing accounted for the largest number of fatalities for the same period with 46 of the 152 deaths recorded attributed to capsizing.

Lucas et al. (2014) studied the effectiveness of a safety program aimed at decreasing the frequency of freezer-trawl (FT) and freezer-longline (FL) fishing vessel accidents. The program discussed is the Alternate Compliance and Safety Agreement (ACSA). In order to meet the program's compliance objectives, operators must adhere to guidance, which includes a section for vessel stability (United States Coast Guard, n.d.). As per the program's outline, operators' best practices are encouraged by ensuring operators have an understanding of basic principles of stability. Additionally, vessels are required to meet minimum requirements regarding watertight integrity and pump capacity. As is discussed in section 5.1, these factors often contribute to loss of fishing vessels from capsizing.

The authors performed statistical analysis that examined accident trends prior to and after implementation of the ASCA program for both FT and FL vessels. As described in detail in the paper, "…reported rates of serious vessel casualties decreased after the vessels reached compliance with ASCA requirements." While this program can be considered a form of imposing stricter regulations, the focus is not on the design of the vessel or its inherent stability. Instead, the ASCA program encourages best practices and improved operator awareness.

2.6 Stability Education Programs

Stability education programs that aim to improve operator awareness are in place outside of Newfoundland and Labrador. An organization in the UK, Seafish, has three different programs in place that vary in complexity. The lowest level stability program that Seafish offers is a half day introduction to stability concepts that is intended for new and inexperienced crew who work on vessels less than 16.5m in length (Seafish, 2014). The outline of the program is presented in Table 1. At the end of approximately 3 hours of instruction, there is a 15-minute evaluation.

Learning outcomes	Assessment criteria. (Be able to)
1. Understand the terms used to describe basic vessel stability	1. Explain the terms used to describe basic vessel stability.
2. Understand the principles of stability	1. Explain the 3 states of vessel equilibrium 2. Explain the righting lever (GZ) in relation to equilibrium 3. Explain what happens to G as weight is added and removed from a vessel 4. Explain the influence that free fluids can have on a vessel including how these influences can be reduced
3. Understand Practical Stability	1. Explain the importance of vessel maintenance 2. Explain the importance of watertight and weathertight integrity 3. Explain the importance of roll period as an indicator of vessel stability 4. Describe how to complete a roll and heel test.

Table 1: Outline of Seafish's ½ Day Stability Course

Seafish offers a more extensive one-day stability education program intended for skippers and experienced crews of vessels less than 16.5m in length (Seafish, 2014). As expected, this program covers more facets and detail of stability than the half-day course. The outline is presented in Table 2. The course includes approximately six hours of instruction and there is a one-hour assessment and ten-minute evaluation. The assessment consists of formative and summative portions. The summative assessment is in the form of a 30-question multiple choice test which participants must obtain a 70% to receive a pass in the course.

Learning outcomes	Assessment criteria. (Be able to)	Learning outcomes	Assessment criteria. (Be able to)
1. Understand the principles of floatation as they apply to fishing vessels	1. Explain the terms used to describe floatation 2. Explain the principles of floatation as they apply to fishing vessels 3. Explain the link between floatation and stability.	6. Understand the free surface effect	1. Explain how fluids can cause the free surface effect 2. Explain how the free movement of fluids influences the stability of the vessel 3. Describe the measures that can be used to limit the free surface effect
2. Understand the terms used to describe basic vessel stability	1. Explain the terms used to describe basic stability 2. Describe how a fishing vessel's center of gravity can be influenced 3. Explain how the metacentre of a fishing vessel is determined 4. Show on a diagram the relative positions of Center of Gravity (G) and Centre of Buoyancy (B).	7. Understand weathertight and watertight integrity and they can effect vessel stability	1. Describe basic fishing vessel design 2. Explain weathertight and watertight integrity linked to vessel design 3. Describe how failures in watertight and weathertight integrity can influence a vessel's stability
3. Understand the difference states of vessel equilibrium	1. Explain the 3 states of vessel equilibrium 2. Explain metacentre (M) and the righting lever (GZ) for various conditions of equilibrium 3. Explain the angle of Loll and how it may be corrected	8. Understand how a seaway can influence a vessel's stability	1. Explain how a sea state can influence a vessel's stability 2. Explain the terms used to describe the period of a roll 3. Describe how the period of roll is used as an indicator of stability 4. Describe roll and heel tests
4. Understand of the movement of weight can influence a vessel's stability	1. Explain how the movement of weight can influence a vessel's stability 2. Explain how the addition of weight can influence a vessel's stability 3. Explain how the removal of weight can influence a vessel's stability	9. Understand the processes used to determine the stability and limits of operation for a vessel	1. List the sources of stability information and guidance 2. List the content of a stability book
5. Understand how the hauling of gear and the landing of catch can influence a vessel's stability	1. Explain how the fishing operations influence a vessel's stability 2. Explain how the landing of catch influences a vessel's stability		

Table 2: Outline of Seafish's 1 Day Stability Course

The most comprehensive stability program offered by Seafish is a more advanced version of the one-day stability program. This is intended for more experienced skippers and covers material in greater detail (S. Potten, personal communication, June 22, 2018). For all three programs, the instructor must be approved by Seafish. Instructors are required to be technically competent and experienced seafarers.

Another stability education program is Fish Safe BC's Fishing Vessel Stability Education Program (introduced in section 2.5). This is a four-day course offered to fishing vessel crew members in BC (Stability Education Course, 2018). At the beginning of the course, participants are given a 98-page binder to be used as both a reference and workbook throughout the course. There is little difference in the deliverables from this course and the course discussed previously from the UK. However, there are four full days to cover the material and more time can be spent going over concepts that are likely to be unfamiliar to participants.

Like Seafish's program in the UK, instructors for Fish Safe's Stability Education Program are experienced seafarers with strong technical skills (J. Krgovich, personal communication, June 12, 2018). The program stresses hands on work to demonstrate technical concepts and makes use of relatable case studies. Coverage of technical concepts is extensive.

In 2008 and 2009, quantitative and qualitative surveys on the program were completed, respectively. The quantitative surveys were completed through questionnaires emailed to participants (Applied Research and Evaluation Services, 2008). The qualitative surveys were completed through two separate focus groups in Richmond and Nanaimo (Lynda Griffiths and Associates, 2009). Results of both surveys were, for the most part, positive. For example, in the quantitative surveys, 96.8% of participants said they learned something from the course, and 94.4% said they would recommend the course to fellow fishers. Furthermore, 62.7% of participants changed their working practices based on what they took away from the course (p.3). These statistics are encouraging and suggest that the program is effectively improving operator practice. The qualitative surveys also had positive results, with participants of the focus group quoting "It dispelled ideas I had previously about what I thought was safe" and "I had preconceived [wrong] ideas of stability" (p.5). The results of both surveys highlight the effectiveness of the program in terms of improving operator awareness.

2.7 Literature Review Summary

As previously stated, the goal of this project is to reduce the frequency of capsizing by identifying primary causes and then finding ways to mitigate risk. The review of the literature indicates that previous studies have looked at fishing vessel capsizing from various perspectives. These studies indicate that capsizing is a relatively rare but highly consequential event. Although preventative regulations exist, there are significant limitations in the regulatory criteria and in terms of operator understanding of the regulatory criteria. Near miss data, which is regularly collected in other industries, has been shown to be a useful tool in both identifying common causes and in improving the safety culture of an operation. However, such data is not currently available in the fishing industry. Finally, stability education has been shown to be a significant contributor to better operating practices and understanding of stability concepts although no specific studies have directly linked stability education and reduction in capsizing frequency.

There has been relatively little research completed that has aimed to determine the primary causes of fishing vessels capsizing. The work that has been done has focused on individual incidents and has attempted to reproduce the accidents through model tests. While some investigations into individual accidents were extensive, a relatively small number of accidents have been studied. As such, the results of the studies were not able to determine broad primary causes of fishing vessel capsizes. Development of technology to assist operators has also been a research focus. It is recognized that operators do not often understand stability books. The authors discuss proposals for “user friendly” technology that warns crews when a vessel’s initial stability is reduced. However, these technologies rely on potentially erroneous input from the crew, which can lead to inaccurate predictions.

Further, these technologies do not give a full description of a vessel's stability characteristics because they do not address large angle stability.

Research on dynamic stability (Johnson and Grochowalski, 2002; Gourlay and Lilienthal, 2002) highlights the complex nature of vessel motions, which cannot be accurately captured by current stability criteria. As a result, stricter regulations or broader application of regulations may still not capture the dynamic effects that dominate capsizing events. These studies suggest that changes to regulations may not have a significant impact on reduction to the number of capsizing events.

The literature review of near misses as they relate to major accidents suggests that reporting near misses may be an effective way to reduce capsizing. Studies that investigated the chemical, manufacturing, and railroad industries all concluded that there are many more near misses than there are major accidents. Jones et al. (1999) and Nielsen et al. (2006) both saw a reduction in major accidents as the reporting of near misses increased, and Wright and van der Schaaf (2004) found the causes of near misses and major accidents to be virtually the same. Therefore, it can be hypothesised that documenting near misses will identify best practices and improve safety culture. Near misses also offer a potential solution to a problem identified by Wang et al. (2005). The authors suggest that fishing vessel accidents often lack information and it can be difficult to determine primary causes. Documenting near misses is a possible solution to this problem.

Much of the literature reviewed has shown that capsizing poses a significant risk to operators largely due to their lack of understanding of vessel stability. There is a dangerous disconnect between naval architects who compose stability booklets and the operators use them. While there has been work done to simplify the stability book, there is still a considerable lack of understanding by operators.

Multiple sources support the idea that the most effective way to reduce capsizing is by improving stability knowledge and awareness of fishing vessel operators. Specifically, Womack (2002), Johnson and Womack (2001), and Howe and Johansen (2007) all identify a lack of operator awareness as one of the leading causes of fishing vessel loss due to capsizing. Howe and Johansen and Loughran et al. (2002) argue that improving operator knowledge of stability can be accomplished by effective training programs.

Other literature suggests that improved awareness is likely to be more effective than stricter regulations in reducing fishing vessel capsizing. This is argued most strongly in Wang et al.'s (2005) research which highlights the tendency for operators to circumvent new regulations, often rendering them ineffective. The authors state the importance of an improved safety culture in the fishing community. Without understanding, new regulations are likely to be circumvented, and the best way to develop a safety culture would be through improved education and training. This approach would also address the incidents that are the result of "negligence/carelessness of the crew." Lucas et al. (2014) concluded that improved operator practice resulted in a reduction in accident rates of US freezer-trawl and freezer-longline vessels. The same rationale may apply to capsize reduction of fishing vessels in NL.

Recognition of the need for educational programs has led to the development of stability education programs in Canada (BC) and the UK. These programs vary in length but the topics covered are generally the same. In BC, qualitative and quantitative surveys were completed to assess the effectiveness of the program. Results from both surveys were positive and participants felt that they had improved awareness following completion of the program. A better way to measure the effectiveness of the program would be through analysis of the number of capsizing events in the province of BC prior to and following implementation of the program. This is currently not being done.

The research in this thesis builds on these conclusions by identifying the primary causes of fishing vessels capsizing through analysis of published investigation reports. An attempt was also made to increase the effective database by investigating the applicability and potential for near miss reporting from interviews with operators. This data was then supplemented with an assessment of operators' understanding of stability based on interviews conducted at the same time as the near miss discussions.

2.8 Research Objective Statement

The primary objective of this study is to determine the common causes of fishing vessel capsizes as a means of proposing rational mitigation measures focused in the most effective areas. This research will take a broad approach by attributing causes to a wide range of published fishing vessel capsizing incidents. Furthermore, the research will attempt to determine if near misses can be used as a tool to supplement published data in identifying common causes. This methodology has proved successful in other industries in reducing accidents.

Until now, research that discusses operators' understanding of stability has been generally anecdotal, with little qualitative or quantitative data available. This research will attempt to assess operator's understanding of stability with qualitative data obtained from interviews and roundtables with fishing vessel operators and crew. Operators' knowledge and the decisions they make during operations will be documented. Correlation between this data and operators' background (i.e. experience and training) will be investigated. An attempt will be made to link the level of stability knowledge of operators and crews in NL with common causes of fishing vessel capsizes.

This link will be discussed as a possible basis to reduce common causes of fishing vessel capsizing. From the conclusions, preventative measures will be recommended to reduce capsizing in Newfoundland and Labrador.

3.0 Relevant Certification Requirements

Background information relevant to the current study is discussed below. This primarily focuses on current stability regulations and requirements for operator training in Canada and specifically in Newfoundland and Labrador.

3.1 Limitations of Current Stability Regulations for Fishing Vessels

Transport Canada (TC) is the governing body for marine vessel regulations in Canada. All vessels must adhere to TC's TP7031E: Stability, Subdivision, and Load Line Standards. Fishing vessels must meet the minimum requirements for STAB 4 of this document. STAB 4 criteria are divided into regulations for Large Fishing Vessel Inspection and Small Fishing Vessel Inspection. Small fishing vessels are vessels with a gross tonnage of less than 150T and length less than 24.4m.

As discussed by Molyneux (2007), STAB 4 requirements match the International Maritime Organization's (IMO) Torremolinos Protocol. This document was written in 1977 and amended in 1993 (IMO, 2018), and it provides guidance on fishing vessel safety and training. The Torremolinos Protocol was updated most recently in 2012 during the Cape Town Agreement (IMO, 2012).

The stability criteria (no ice accumulation) as outlined by STAB 4 is presented in Table 3 and Table 4.

Angle of Heel, θ (degrees)	Area Under GZ Curve (m·radians)
θ < 30°	0.055
θ < 40°	0.09
30° < θ < 40°	0.03

Table 3: Minimum Area under GZ Curve Requirements

Angle of Heel, θ (degrees)	Righting Lever, GZ (m)
θ > 30°	0.2

Table 4: Minimum Righting Lever Requirement

Further, the maximum righting arm, GZ, must occur at an angle of heel between 25° and 30°, and the transverse metacentric height (GM), must be at least 0.35 m. The regulations require calculation of GM via an inclining experiment and the submission of hydrostatic curves in the form of a stability booklet.

While TC and IMO regulations require vessels to have sufficient static stability, there exist significant gaps as applied to fishing vessels. First, as pointed out by Gourlay and Lilienthal (2002) and Johnson and Grochowalski (2002), these regulations are based on static stability requirements and it is well understood that capsizing is often the result of dynamic action in wind and waves. The requirements for area under the GZ curve do consider the capacity of the vessel to absorb roll energy but this is an empirical measure and does not encompass wave heading, resonance, damping, or other parameters that affect seakeeping and a vessel's predicted roll behaviour in waves.

The regulations do not apply to small fishing vessels (SFV) less than 24.4m in length with a gross tonnage less than 150 tons. For most species, if a vessel meets the SFV criteria, there is no requirement to evaluate the stability of the vessel. If fishing for pelagic species such as mackerel, herring, or capelin, operators of SFVs must meet certain stability criteria.

In many instances, a SFV's stability has been analyzed following capsize to find that it does not meet STAB 4 requirements (Transportation Safety Board of Canada, 2006). Many small fishing vessels operate with inadequate stability because regulations do not require stability assessment.

The lack of regulations for small fishing vessels has long been recognized as a problem in Canada. Coming into effect July 13, 2018, any new fishing vessel constructed over 9m in length will is required to "successfully undergo a stability assessment by a competent person" (Transport Canada, 2017). While this is an improvement, most vessels operating for the foreseeable future were constructed prior to July 2018 and will not need to perform a stability assessment; the more lenient regulations are still relevant for the majority of fishing vessels.

An important, and infrequently discussed, aspect of regulations, as they apply to fishing vessels, is the operator's understanding of stability books and how they are used. This is discussed further in section 5.1, but in many cases, operators of fishing vessels do not understand how to properly use stability booklets. Womack (2002) writes that stability booklets and letters are often "incomprehensible" to crews and operators. The stability assessment, which is expensive and time consuming, is disregarded. Even the most extensive stability assessments can be ineffective because they are often not understood or followed by operators.

3.2 Formal Stability Training Requirements in Canada for Operators

Operators' understanding of stability is likely a function of formal training. The level of training required to operate a given vessel depends on the vessel's tonnage and its operational area. Skippers of fishing vessels in Canada are required to hold a certificate listed in Table 5 (Transport Canada, 2016).

Certificate	Validity [1]	Areas of Operation	Max Vessel Gross Tonnage
Fishing Master, First Class	The holder of this certificate may act as Master of a fishing vessel of any tonnage engaged on an unlimited, near coastal or sheltered waters voyage.	Unlimited	Unlimited
Fishing Master, Second Class	The holder of this certificate may act as Master of a fishing vessel of any tonnage engaged on a near coastal or sheltered waters voyage and as Chief Mate of a fishing vessel of any tonnage engaged on an unlimited voyage.	Coastal/sheltered Waters	Unlimited
Fishing Master, Third Class	The holder of this certificate may act as Master of a fishing vessel of any tonnage engaged on a near coastal or sheltered waters voyage and as Officer in charge of the watch of a fishing vessel of any tonnage engaged on an unlimited voyage.	Coastal/sheltered Waters	Unlimited
Fishing Master, Fourth Class	The holder of this certificate may act as Master on board a fishing vessel of not more than 100 gross tonnage engaged on a near coastal or sheltered waters voyage and as Officer in charge of the watch of a fishing vessel of any tonnage engaged on near coastal and sheltered waters voyage.	Coastal/sheltered Waters	100
Certificate of service as Master of a fishing vessel of less than 60 Gross Tonnage	The holder of this certificate may act as Master on board a fishing vessel of not more than 60 gross tonnage engaged on an unlimited, a near coastal, class 1 or 2 or a sheltered waters voyage, according to the voyages on which the qualifying service for the certificate has been acquired. The validity will be specified on the certificate.	Unlimited [2]	60
1) As described in Transport Canada's *The Examination and Certification of Seafarers* (2016)			
2) Validity of area of operation depends on the operator			

Table 5: Transport Canada Certification Requirements

The training required for each certificate is more rigorous at the top of the table and less sophisticated towards the bottom. An operator with a Fishing Master, First Class certificate is required to undertake the greatest amount of training, with operator training decreasing towards Master of a Fishing Vessel of less than 60 GT.

The training that an individual must undertake to obtain a certificate is described in Transport Canada’s document, *The Examination and Certification of Seafarers* (2004; 2007; 2016). The most recent edition of this document was published in 2016. However, previous revisions were released in 2007 and 2004. See Table 6 for revisions that have impacted stability training for operators.

Certificate	Stability Education/Training Courses		
	Rev 6 (2016)	Rev 5 (2007)	Rev 4 (2004)
Fishing Master, First Class	SCS [1] Level 2	SCS Level 2	Ship Stability
Fishing Master, Second Class	SCS Level 2	SCS Level 2	Ship Stability
Fishing Master, Third Class	SCS Level 2	SCS Level 2	Ship Stability
Fishing Master, Fourth Class	SCS Level 1	SCS Level 1	None
Certificate of service as Master of a fishing vessel of less than 60 Gross Tonnage	None	None	None [2]
1) SCS: Ship Construction and Stability			
2) For this revision, the max tonnage for this certificate was 100T			

Table 6: Stability Training for Fishing Vessel Operator Certificates

Both SCS Level 1 and 2 (and "Ship Stability" prior to 2007) courses provide participants with an extensive overview of ship stability principles. An operator that has passed an examination for these courses should be well equipped with a sound knowledge and understanding of stability. Available descriptions of the courses are listed in *The Examination and Certification of Seafarers,* which can be accessed online.

Upon review of Transport Canada regulations, it can be inferred that operators with a First, Second, or Third Class certificate have received an education that equips them with a sound understanding of stability. Following changes to regulations in 2007, operators with a Fourth Class certificate would also have obtained some understanding of stability. Operators with a certificate for a vessel less than 60T or those with a Fourth Class ticket prior to 2007 are assumed to not have received any formal stability training.

3.3 Vessel Length Restrictions in Newfoundland and Labrador

Fishing vessels operating offshore Newfoundland and Labrador have been identified as generally having design features that have a detrimental effect on stability (Wiseman and Burge, 2000). The Department of Fisheries and Oceans (DFO) imposed vessel replacement regulations in the 1990s based on fish stock conservation (DFO, 2002). In order to limit the amount of fish that could be stowed in a single trip, DFO's policy on issuing new licences restricts many vessels to an overall length of 19.8m (65 feet) (DFO, 1996). Wiseman and Burge identify these regulations as a safety issue for fishing vessels. Although vessel length is restricted, beam and depth are not restricted and this results in pressure to increase these dimensions to accommodate additional catch and/or extra fishing gear. This results in vessels that are poorly proportioned.

The authors also explain that stability of the vessel is reduced by loading conditions during operations. Loading is restricted by the vessel's length, and the loading conditions often raise the center of gravity due to the inability to spread catch or equipment lengthwise. Furthermore, the vessel's size and proportions, as limited by regulations, does not make the vessel well suited for harsh weather. This is when the vessel would see the most significant roll action in large waves and require sufficient reserve buoyancy to right itself.

4.0 Research Methodology and Data Collection

The first component of this study is to determine the primary causes of fishing vessel capsizes. In many countries, accidents resulting in injury, fatality, significant property loss, or environmental damage lead to an investigation and an accompanying report by the respective country's government. The primary source of capsize accident data collection for this project is published investigation reports. While reports are published ranging from different types of accidents to different types of vessels, only reports of fishing vessels capsizing were of interest for this project. For each incident report, the causes that contributed to the capsizing were identified. Incident reports are available online for different countries. Most sites are searchable, and it was necessary to filter for reports that relate to the capsizing of fishing vessels.

In the next stage of the research, individual interviews were conducted with fishing vessel operators. The original motivation for this approach was to supplement the data from investigation reports with near miss events. The interviews were seen as a possible way to document near misses, a practice that is not currently done in the commercial fishing industry. It is also intended to assess the utility of such data in terms of operator willingness to report and operator ability to describe cases including potential causes and effects. As explained by Wright and van der Schaaf (2004), accidents are rare compared to near misses. If accidents could be supplemented by a much greater number of near misses, common causes could be identified with greater confidence. However, the Newfoundland and Labrador Fish Harvesters Safety Association (NLFHSA) recommended that the approach be broadened to include other factors such as operators' understanding of stability and how they perceive the risk of capsizing in addition to a discussion of near misses.

Finally, roundtable discussions with commercial fish harvesters were conducted. This also stemmed from a recommendation from the NLFHSA. Roundtable discussions included multiple participants and allowed for a wider range of qualitative data. In addition to collecting near miss incidents, these discussions focused on how fish harvesters determine whether their vessel is stable or not. Perceived risk of vessel capsizing was also covered in the discussions. Another point of interest was how harvesters use their stability book and the perceived effectiveness of current regulations. The findings of these discussions were compared to the previous work covered in the literature review.

The interview and roundtable portions of the study were approved by Memorial University's Interdisciplinary Committee on Ethics in Human Research (ICEHR). Prior to an interview or roundtable taking place, all participants signed a consent form.

Common trends identified in the investigation reports were highlighted and are discussed in detail in section 5.1. Interviews and roundtables were conducted in large part to provide an assessment of operators' understanding of stability and perception of risk. Discussions allowed the rationale behind operational decisions to be explored. This information is currently not available from investigation reports alone. Operators' knowledge of stability is also an important factor to consider, and discussions investigated the impact of an inadequate knowledge of stability on operations. Interviews and roundtables with operators also brought up topics such as stability analysis and additional training. In both individual interviews and roundtable discussions, operators were specifically asked about any near misses they may have had. Answers to this question provided additional quantitative data to supplement analysis of investigation reports.

4.1 Investigation Reports

In many countries, governing agencies publish investigation reports after an accident occurs. In the event that a fishing vessel capsizes, investigation reports are made available to the public. Typically, these reports discuss the vessel history and crew experience, the history of the voyage, and factors that may have contributed to the vessel's capsizing.

Data is available from many countries. As this project emphasizes commercial fishing in NL, Canada's Transport Safety Board's database of marine accident investigation reports was the primary source of information. This online database includes accidents of all types to all vessels in Canada dating back to 1990. Prior to 1990, investigation reports are available in archives. For this project, greater relevance was placed on reports that are more recent and only investigation reports available online were analyzed. As stated, this database includes all types of accidents to all vessels. The data base was filtered with criteria:

1. Vessel: commercial fishing vessel
2. Accident type: capsizing

To supplement commercial fishing vessel capsizes in Canada, other countries investigation reports were also analyzed. These included reports from the United States, Norway, Ireland, Australia, and the UK. For each report the following information was noted:

1. Vessel Name
2. Vessel Particulars (Length, Beam, Draft, Displacement)
3. Date
4. Weather Conditions (Wind and Waves)
5. Primary Causes

The last category in the list above, “Primary Causes” was of the most interest. Common causes were identified and highlighted.

4.2 Interviews

Anonymous interviews were conducted with individuals who had experience as a fish harvester (crew or skipper). The original premise was to limit interviews to discuss near miss capsizing events. However, the NLFHSA recommended that the approach be altered because it would likely be difficult to recruit participants on the basis of a near miss capsizing event. This was due to operators possibly lacking the awareness to recognize that they had been involved in a near miss or being reluctant to speak about an incident that could fault their behaviour or decisions.

The approach was altered in order to speak with individuals about their fishing experience. Individuals were recruited to discuss the risk of capsizing and their understanding of stability. Following this first part of the interview, each individual was asked if they had had a near miss experience and if they would like to discuss it. Changing the approach of the interviews resulted in more volunteers coming forward to take part. Recruitment of interviewees was originally done through the NLFHSA, but was later expanded to “cold calling” participants based on names provided from industry contacts. The interviews were structured as follows:

1. General information: experience, vessel size, species
2. How do you know/determine if your vessel is stable?
3. Do you have a stability book? Do you think they are useful?
4. How do you maintain the stability of your vessel?
5. What poses the largest risk to your vessel capsizing?
6. What do you think is the most effective way to reduce/prevent capsizing (stability books/stability testing, formal stability training, educational programs)?
7. Have there been instances where you felt the stability of your vessel was compromised and close to capsizing? If so, can you please explain the event?

The responses from the interviews allowed for operators' understanding of stability to be studied and assessed. Assessing operators' understanding of stability was the primary objective of the interview process. This was an important consideration and provided a benchmark to compare with research that relates capsizing to operators' understanding of stability. Further, any near misses that were documented would be used to supplement the data from the investigation reports.

4.3 Roundtables

The final portion of research was roundtable discussions that focused on operators' understanding of stability and how they perceived the risk of capsizing. The only criterion for participation was that individuals have experience working on a commercial fishing vessel. All recruitment of participants was done through the NLFHSA.

The goal of the roundtables was to gain insight into the level of stability knowledge of operators. The roundtable format allowed for a more casual discussion than the interviews. The discussions were guided by a chairperson, but in general, participants were encouraged to pursue any topic that they considered relevant to the discussion on stability and capsizing. The structure of the discussion is as follows:

1. General information: experience, vessel size, species
2. What does it mean to have a stable vessel?
3. How do you maintain the stability of your vessel?
4. What poses the largest risk to the stability of a vessel?
5. Have there been instances when you have felt: 1) that the vessel's stability was compromised or 2) that your vessel was close to capsizing?
6. What would you consider the most effective way to reduce/prevent the loss of stability or capsizing?

For a detailed roundtable outline, see Appendix A. As with the interviews, this research provided information not available in investigation reports. While investigation reports often hypothesize about an operator's knowledge of stability based on the outcome of the incident, they do not provide any assessment of the general level of understanding of stability amongst operators. Roundtables attempted to assess this parameter qualitatively and determine in what areas operators were lacking.

5.0 Results

The following sections discuss the results of the three forms of research undertaken: analysis of investigation reports, interviews, and roundtable discussions with operators.

5.1 Investigation Reports

In order to determine the primary causes of fishing vessels capsizing, investigation reports were analyzed. For this project, investigation reports from Canada, the United States, Norway, Ireland, and Australia were studied. In order to meet criteria for the study, the vessel must have been a fishing vessel and it must have capsized (i.e. grounding, man overboard, etc. were not included). Investigation reports referenced are available to the public. There were a total of 60 reports analyzed for the project. See Table 7.

Country	No. of Reports Analyzed
Canada	32
United States	6
Ireland	7
Norway	3
Australia	1
United Kingdom	11
Total	60

Table 7: Investigation Reports Analyzed by Country

Following analysis of the reports, common causes of capsizing were identified. For a complete list of events and summaries see Appendix B-1 and Appendix B-2. Appendix B-1 includes details of the vessels involved in each incident, while Appendix B-2 provides details on the causes determined to contribute to each capsizing incident. For each investigation report, the cause (or causes) of the event could be placed into one of four major categories.

1. Operator’s practice
   - Unsafe loading
   - Knowingly operating with watertight integrity compromised
   - Knowingly operating with the free surface effect present
   - Operating in excessively harsh weather
2. Unsafe modifications
3. Lack of maintenance
4. Small scale design flaws
   - Insufficient freeing ports
   - Insufficient bilge pumps
   - Equipment installed that increased center of gravity

“Operator’s practice” and “Small scale design flaws” are divided into subcategories. Each of these is discussed with an example provided for illustrative purposes (see section 6.6). Capsizing is often due to a combination of two or more of these causes. It is also important to note that while it is not considered a cause, many vessels were not required to meet any stability regulations. The lack of regulatory requirements will be reviewed in relation to the primary causes listed above.

Table 8 and Table 9 list all investigation reports of capsizing events that were analyzed and their associated causes. The frequency of different causes and sub-causes is illustrated in Table 12 and Figure 3. Table 10 outlines the percentage of incidents that each of the four primary causes contributed to. Table 11 shows the total number of times a cause was determined to contribute to an incident.

For each incident, there were often multiple causes and sub causes. For example, as per Table 10, operator’s practice contributed to 57 of the 60 incidents. However, in many cases, multiple causes played a role. Such was the case for *Ryan’s Commander*, in which unsafe loading and operating with watertight integrity compromised were determined to contribute to the capsizing. For that single incident, two examples of operator's practice were tabulated as part of the 86 examples highlighted in Table 11.

Following analysis, accident trends in the Canadian fishing industry from 2004 to 2017 were examined. This data is publicly available in the form of an excel file. This analysis was only performed for Canada because other countries did not provide such extensive data. The incidents were also sorted by vessel size to determine if there was any relationship between the size of the vessel and the likelihood of an incident occurring. These analyses are discussed in sections 6.2 and 6.3, respectively.

No,	Country	Vessel Name	Year	Operator's Practice					Unsafe Modifications that Reduced Stability	Lack of Maintenance that led to an Ingress of Water	Poor Design			
				Unsafe Loading	Operating with F.S.	Operating with watertight integrity (knowingly) compromised	Operating in harsh weather	Other			Freeing ports insufficient	Bilge pumps and/or alarm system insufficient	Equipment installed in location that increased COG	Other
1	Canada	Ryan's Commander	2004	✓		✓					✓		✓	
2	Canada	Lannie & Sisters II	2006			✓				✓	✓	✓		
3	Canada	Melina & Keith II	2005			✓			✓		✓			
4	Canada	Big Sister	2007	✓		✓				✓		✓		
5	Canada	Cape Fin-Tose	2006	✓				✓						
6	Canada	L' Acadien II	2008					✓						
7	Canada	Strait's Pride II	1990				✓							✓
8	Canada	Miss Cat Harbour	1997	✓		✓		✓						
9	Canada	Cap Rouge II	2002	✓					✓	✓				
10	Canada	Hope Bay	2004	✓						✓				
11	Canada	Prospect Point	2004					✓	✓					
12	Canada	Ocean Tor	2005			✓				✓				
13	Canada	Sea Urchin	2007	✓		✓								
14	Canada	Love and Anarchy	2008	✓					✓	✓				✓
15	Canada	Le Marsouin I	2009	✓		✓								
16	Canada	Craig and Justin	2010	✓		✓								
17	Canada	Jessie G	2012	✓					✓					
18	Canada	Pacific Siren	2012	✓				✓	✓					
19	Canada	Caledonian	2015	✓					✓					
20	Canada	Lady Devine	1994	✓		✓	✓							
21	Canada	Courageous	1995	✓	✓									
22	Canada	Dalewood Provider	1995	✓					✓	✓				
23	Canada	Stephane P II	1996	✓										
24	Canada	Inskip	1995	✓	✓									
25	Canada	3J'S '93 (THE)	1996	✓			✓				✓			
26	Canada	CFV 151816	1997	✓										
27	Canada	C19496NB	2016					✓						
28	Canada	Five Star	2014	✓		✓	✓		✓					
29	Canada	Le Bout de Ligne	1990				✓							✓
30	Canada	Sea Serpent 25	2014			✓						✓		

Table 8: Investigation Reports and Causes (1/2)

No,	Country	Vessel Name	Year	Operator's Practice					Unsafe Modifications that Reduced Stability	Lack of Maintenance that led to an Ingress of Water	Poor Design			
				Unsafe Loading	Operating with F.S.	Operating with watertight integrity (knowingly) compromised	Operating in harsh weather	Other			Freeing ports insufficient	Bilge pumps and/or alarm system insufficient	Equipment installed in location that increased COG	Other
31	Canada	CFV #132145	1993	✓										
32	Canada	Sea Gypsey	2009			✓								
33	Ireland	Carraig An Isac	2011	✓										
34	Ireland	Catherine L	2005				✓							
35	Ireland	Honeydew II	2007			✓								
36	Ireland	Kyle Mhor	2000	✓		✓								
37	Ireland	Dinsih	2006						✓	✓				
38	Ireland	Rising Sun	2005	✓					✓					
39	USA	Katami	2008	✓		✓	✓		✓		✓			
40	USA	Advantage	2012						✓					
41	USA	Christopher's Joy	2014					✓	✓					
42	USA	Hawaii Five-1	2015	✓		✓		✓						✓
43	USA	Lydia and Maya	2016	✓		✓		✓						
44	USA	Evanick	1998	✓										
45	USA	FV Lady Mary	2009			✓			✓					
46	Norway	Viking 7	2014	✓										✓
47	Norway	Marina	2009	✓										
48	Norway	Monica IV	2009	✓							✓			
49	Austrailia	Tamara	2002						✓					✓
50	UK	FV Sally Jane SM74 (1997)	1998	✓					✓		✓			
51	UK	FV Sally Jane SM74 (2013)	2013	✓		✓		✓					✓	
52	UK	Bounty	2005	✓							✓			
53	UK	Fraoch Ban	1999		✓									
54	UK	Angela	2001	✓						✓				
55	UK	Kairos	2015				✓	✓						✓
56	UK	FV Harvest Hope	2005			✓			✓		✓			✓
57	UK	FV Flamingo	2002	✓		✓		✓	✓					
58	UK	FV Sundance	2001	✓							✓			✓
59	UK	FV Stella Maris	2014	✓					✓		✓		✓	
60	UK	Majestic	1989	✓		✓								

Table 9: Investigation Reports and Causes (2/2)

Cause	No. of Incidents Involving Cause	Percentage of Total Accidents
Operator's Practice	57	95.0%
Unsafe Modifications that Reduced Stability	20	33.3%
Lack of Maintenance that led to an Ingress of Water	9	15.0%
Poor Design	21	35.0%

Table 10: Number of Incidents Involving Causes

Cause	Frequency
Operator's Practice	86
Unsafe Modifications that Reduced Stability	20
Lack of Maintenance that led to an Ingress of Water	9
Poor Design	26

Table 11: Frequency of Capsizing Causes

Cause		Frequency
Operator's Practice	Unsafe Loading	40
	Operating with F.S.	3
	Operating with watertight integrity (knowingly) compromised	23
	Operating in harsh weather	8
	Other (Operator's Practice)	12
Unsafe Modifications that Reduced Stability		20
Lack of Maintenance that led to an Ingress of Water		9
Poor Design	Freeing ports insufficient	11
	Bilge pumps and/or alarm system insufficient	3
	Equipment installed in location that increased COG	3
	Other (Poor Design)	9

Table 12: Frequency of Capsizing Causes and Sub-causes

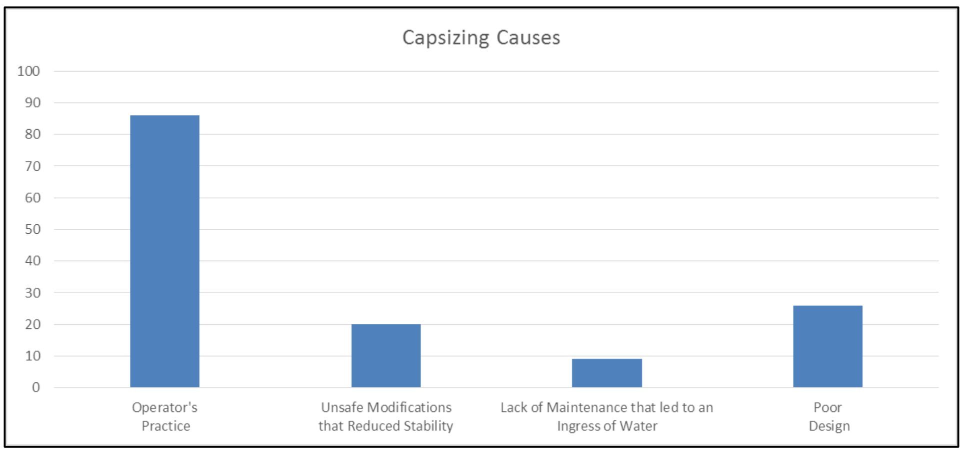

Figure 2: Frequency of Capsizing Causes

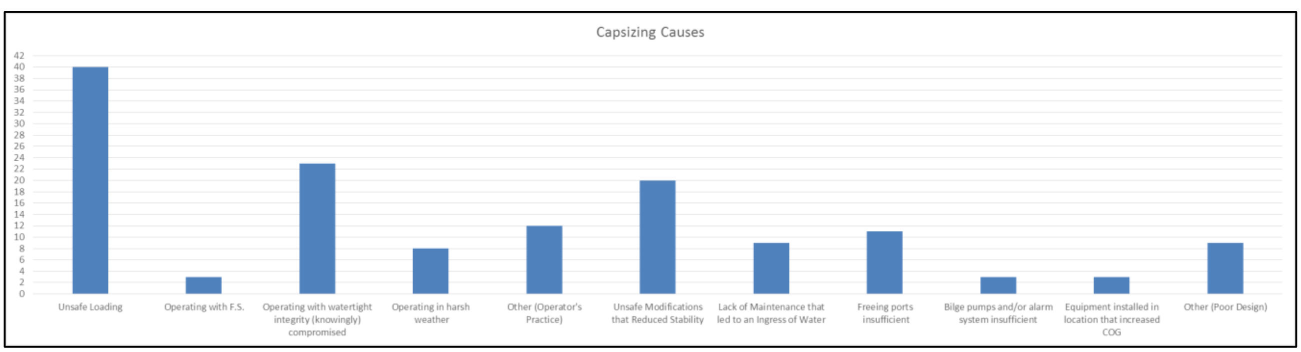

Figure 3: Frequency of Capsizing Causes and Sub-causes

5.1.1 Common Causes

The common causes identified in section 5.1 are discussed in greater detail in the following sections.

5.1.1.1 Operator’s Practice

One of the most important contributing factors to capsizing was poor practice on behalf of operators. Investigation reports identified this as a common occurrence, with improper loading, operating with a free surface effect, and operating in poor weather conditions to be common examples of poor practice. As per Table 10, operator’s practices played a role in 57 of the 60 incidents. Amongst the 60 incidents analyzed, there were a total of 86 examples of operator’s practice that contributed to a vessel capsizing (see Table 12). With 40 occurrences, the most common sub-category of operator’s practice was unsafe loading. This was followed by operating with watertight integrity knowingly compromised (23), operating in harsh weather (8), operating with a free surface (3), and other (12).

One of the most common examples of operators’ poor practice is improper loading of the vessel. Cases of improper loading often resulted in an increase in the vessel’s vertical center of gravity (COG). Raising the COG reduces a vessel’s metacentric height and stability. Examples of increasing the COG include storing heavy gear on upper decks or removal of permanent ballast near the keel of the vessel. Overloading the vessel was also identified as a serious problem. Overloading can significantly change the displacement from the values used in the stability book (if there is one) and reduces the vessel’s freeboard. Many investigation reports concluded that the operators would operate the vessel under loading conditions not accounted for in the stability book.

Two other examples of poor practice identified in investigation reports was operating with a free surface or operating with watertight integrity knowingly compromised (i.e. a leak or watertight compartments not shut). Vessels operating with a free surface experience a reduction in stability because of the free surface effect. Munro-Smith (1967) explains that the free surface effect occurs in any fluid in a ship's tank or compartment which has a surface slope that changes when the ship rolls (i.e. any tank or compartment that is not 100% or 0% full of fluid). As the fluid surface changes with ship motions, so does the location of the fluid's center of gravity. The free surface causes a lateral shift of the ship's center of gravity. The effect of this shift, as Munro-Smith states, "…is generally expressed as being equivalent to raising the center of gravity…" (Munro-Smith, 1967, p.208). The equivalent rise in the ship's center of gravity reduces its stability.

Vessels that take on water through leaks or flooding become subject to the free surface effect. Some capsizing events occurred due to flooding because watertight doors or compartments were not fastened shut as they should have been. When the vessel begins to flood, many crews continue to operate because they do not realize that the stability of the vessel is being reduced. Operating with a flooded vessel also reduces freeboard, changes the displacement, and reduces reserve buoyancy and the vessel's righting moment. As the vessel's stability is reduced, it becomes more susceptible to capsizing.

A final example of poor practice that was a common theme in the investigation reports was vessels operating in adverse weather conditions. When given sufficient storm warning, many operators continued to fish instead of seeking shelter from high winds and waves. These harsh environments can cause large heeling moments and shipped water which can lead to flooding.

5.1.1.2 Unsafe Modifications

A second common theme contributing to capsize accidents was unsafe modifications made to a vessel that reduced the vessel's stability and made it more susceptible to capsizing. This is another form of operator decision but it concerns the design rather than the operation. Of the 60 investigation reports, unsafe modifications were a factor in 20 incidents. It was found that modifications typically consisted of the addition of equipment such as a winch or crane. Adding large, heavy equipment has two effects on the vessels' stability: the displacement increases and the center of gravity changes. As many modifications identified in the investigation reports were above deck level, the center of gravity of the vessel was most often raised, thus reducing the vessel's stability. When owners have had analysis performed to assess the stability of their vessel (i.e. an inclining experiment or a stability book), changes to the vessel that have an impact on the displacement and center of gravity are significant because they render the stability information inapplicable.

For SFVs, owners are not always required to meet any stability requirements. Therefore, when there are modifications to the vessel, regardless of the work done, there is often no requirement for the owner to alert regulatory authorities of the changes or reassess the vessel's stability. For vessels required to meet stability requirements, TC regulations state that "in the case of a vessel for which the stability information required by this section is available, that stability information shall be modified and submitted to the Board for approval" (Government of Canada, 2017). Transport Canada recognizes the need to keep track of changes to the vessel that may have an effect on the vessel's stability and has issued bulletins in the past outlining procedures to track modifications (Transport Canada, 2017). However, cases were identified in which vessel owners did not track changes or reassess the vessel's stability. As a result, the stability of the vessel was reduced, and the previous stability calculations were no longer valid.

5.1.1.3 Lack of Maintenance

Another trend, identified from the investigation reports, was the lack of maintenance of fishing vessels. The most common impact of poor maintenance was ingress of water to a vessel due to a loss of watertight integrity. This was the case for nine of the 60 incident reports. Typically, water would find its way into the vessel through hatches on the deck or hull that should have been watertight. Due to a lack of upkeep, the hatches were often unable to keep water from entering the vessel and flooding was common. Furthermore, cases were identified in which bilge pumps were not working. As a result, the vessel was unable to rid itself of shipped water and flooding could not be prevented. Flooding is detrimental to a vessel's stability as it introduces the free surface effect and changes the displacement of the vessel.

5.1.1.4 Small Scale Design Flaws

Small scale design flaws that are not directly related to a vessel's inherent stability were identified as a contributor to fishing vessels capsizing. Unlike issues relating to stability regulations discussed in section 3.1, these were often smaller design details that had an adverse effect on the vessel's stability. 21 of the 60 incidents were, at least in part, the result of these design flaws. The most common design flaws identified from a review of incident reports prevented vessels from dealing with shipped water. Freeing ports, bilge pumps, and alarm systems were often identified as causal or contributing factors.

Issues relating to freeing ports were:

- Freeing ports insufficiently sized. The area of the freeing ports was less than required by regulation. This prevented shipped water from clearing the deck of the vessel.
- Freeing ports not equipped with flaps to prevent water from entering the deck.
- Freeing ports welded shut. This would prevent shipped water from clearing the deck.

Lack of bilge pumps often prevented the vessel from being able to remove water once flooding occurred. Further, some vessels lacked an alarm to alert the operators that flooding had occurred. Operating with design flaws mentioned above suggest that operators may not be aware of the risk of shipped water and the effect it can have on a vessel's stability.

5.1.2 Stability Regulations and Capsizing

While regulations (or lack thereof) cannot "cause" a vessel to capsize, it is important to consider the role regulations have in relation to the frequency of fishing vessels capsizing. Regulations governing a vessel's stability depend on the country the vessel is registered. However, as discussed by Molyneux (2007), regulations around the world are generally adopted from IMO's Torremolinos Protocol, which came into effect in 1977 and updated in 2012. These regulations, and those adopted from them, do not have stability requirements for vessels less than 24m in length. Of the 60 investigation reports analyzed, 53 involved vessels that met TC's length and displacement requirements for SFV classification.

Despite the majority of vessels meeting SFV dimensions, only 35 of the 60 vessels did not have any stability assessment performed. 25 of the 60 vessels had some stability analysis performed, although in some cases the stability data was up to date as it should have been[1]. Stability analysis refers to either an inclining test to determine the vessel's initial stability or an entire stability book. The fact that approximately 42% of the vessels investigated had stability assessed indicates that requiring operators to produce stability data is not a fully effective means of capsizing prevention.

As discussed in section 2.3, even when a vessel must adhere to stability regulations, there still exists a significant risk of capsize. Capsizing is often, at least partially, due to dynamic action in large waves. The motion of the vessel can be predicted by seakeeping methods that are based on vessel accelerations (Gourlay and Lilienthal, 2002; Johnson and Grochowalski, 2002). The IMO Torremolinos Protocol does not account for vessel dynamics, and therefore does not capture the full risk of capsizing. The fact that when vessels do follow stability regulations there still exists a significant chance of capsizing is an important consideration. It reinforces the concept that reducing the frequency of fishing vessel capsizing is more likely to occur through more informed operator decisions as opposed to more stringent regulation.

5.2 Near Miss Capsizing Events from Interviews and Roundtables

Interviews with fishing vessel operators were originally intended to investigate the utility and applicability of near miss data as a supplement to the data presented in the formal accident reports. This strategy was adapted from other industries where it has been shown to be successful (Wright and van der Schaaf, 2004; Jones at al, 1999; Nielsen et al., 2006). During the course of interview planning with the NLFHSA, the approach to fishing vessel operators and crew was broadened to include questions on stability knowledge and training

[1] Not all reports explicitly stated if stability analysis had been performed or to what degree. In some cases, assumptions were made based on the vessel's size and regulations.

in addition to the near miss information. In the following sections, the near miss data is discussed separately from the stability knowledge data although both were gathered in the same individual interviews and roundtables.

The interviews and roundtables included a question that asked if participants had experienced a near miss capsizing event. If they had, they were asked to provide details surrounding the incident. Based on their description, causes were determined. Compared with the thorough investigation reports studied in section 5.1, details provided with the near miss incidents were typically sparse. In many cases, it was difficult to confidently assign causes to the events. The causes as they were understood are outlined in Table 13.

Operator's practice played a role in 11 of the 13 near miss capsizing events. While the sample size is relatively small, these numbers reinforce the results of section 5.1. As per Table 10, operator's practice was a factor in 95% of the investigation reports analyzed. While the operator's practice for near misses was not as frequently noted as the cause of the incident, it played a role in the majority of incidents (84.6%).

Beyond operator's practice, the other causes do not align as well with section 5.1. This discrepancy is likely because there is no extensive investigation report that follows a near miss event to identify these less frequent causes. It is probable that the details provided by interview and roundtable participants were not thorough enough to capture all of the causes that contributed to the near miss. This may have been due to either the participants not being aware of other factors, or purposefully withholding details.

No.	Name	Source	Operator's Practice					Unsafe Modifications that Reduced Stability	Lack of Maintenance that led to an Ingress of Water	Poor Design			
			Unsafe Loading	Operating with F.S.	Operating with watertight integrity (knowingly) compromised	Operating in harsh weather	Other			Freeing ports insufficient	Bilge pumps and/or alarm system insufficient	Equipment installed in location tha increased COG	Other
1	Near Miss 1	Roundtable 1				✓	✓						
2	Near Miss 2	Roundtable 1	✓										
3	Near Miss 3	Roundtable 2	✓	✓									
4	Near Miss 4	Roundtable 2		✓			✓						
5	Near Miss 5	Roundtable 2						✓					
6	Near Miss 6	Roundtable 3				✓							
7	Near Miss 7	Interview 4				✓							
8	Near Miss 8	Interview 6				✓							
9	Near Miss 9	Interview 9	✓						✓				
10	Near Miss 10	Interview 11	✓										
11	Near Miss 11	Interview 12				✓							
12	Near Miss 12	Interview 14											✓
13	Near Miss 13	Interview 16				✓			✓				

Table 13: Near Misses from Interviews and Roundtables

5.2.1 Description of Near Misses from Interviews

The near miss incidents discussed during interviews are summarized below.

5.2.1.1 Participant 4

Participant 4 spoke of a near miss in which the crew was operating in relatively harsh weather. At around 3:00 a.m., a beam sea wave struck the vessel and caused a large roll to port. The participant said that the vessel returned to its even keel position quickly and he did not feel that, despite the harsh weather, the vessel was in significant danger. He stated that as they were in harsh weather, the crew took precautions and ensured that the height of the loads above the keel was kept as low as possible.

5.2.1.2 Participant 6

Participant 6 was hauling crab pots off the Grand Banks when he encountered harsh weather. The day's forecast originally called for light winds but the weather picked up while they were hauling pots. Upon being alerted of the coming weather, the participant removed all of the crab pots from the deck and put them back in the water. In the harsh weather, a wave hit the vessel and it experienced a large angle of roll. The participant said that it was approximately 25 to 30 seconds before the vessel rolled back to an upright position. The participant said that he was worried that the harsh weather would cause the vessel to capsize.

5.2.1.3 Participant 9

Participant 9 was fishing when a pipe to the refrigerated seawater (RSW) tank broke which led to an ingress of water. A crew member said to the participant that they thought the vessel's behaviour was abnormal. The participant checked the below deck videos and found the leak. The vessel was taking on water faster than the bilge pump could clear the water. When the leak occurred, there was close to 600 crab pots and 5000 lbs of bait on the deck of the vessel which increased the center of gravity. The participant used an emergency pump to clear the water and repaired the broken pipe.

5.2.1.4 Participant 11

Participant 11 was fishing when a large list occurred to his vessel. While fishing on a "poor day," there was gear and catch on deck that was not strapped down. The load on the deck shifted "to one side" and a list occurred. The crew changed the direction of the vessel and used the wind to correct the list.

5.2.1.5 Participant 12

Participant 12 lost a vessel while fishing. While this would exceed what is considered a "near miss," it is included in this section because the data was collected with other interviews. Participant 12 said he took on water through the stern of the vessel which led to the vessel sinking. The participant said he did not realize the vessel was taking on water until it was too late. The participant was unable to provide many details surrounding the incident. As such, it is difficult to confidently attribute a cause to the incident.

5.2.1.6 Participant 14

Participant 14 said he was not involved in a near miss experience himself, but he knew of a fellow operator who was. During the near miss incident, the operator was hauling capelin over the side of the vessel. As they started pumping the load on board, the capelin began to die and sink in the net. This resulted in a heeling moment and a list occurred. The crew let the capelin go and the vessel returned upright.

5.2.1.7 Participant 16

Participant 16 said he had approximately 48,000 lbs of capelin on board when the vessel encountered strong winds. It was discovered that the lazerette pump was not working and they were unable to dewater the capelin. As a strong wind hit the vessel, the load shifted and the vessel began to sink by the stern. They were able to avoid loss of the vessel and were escorted back to port by another vessel. However, the participant felt that loss of the vessel was likely and said "I thought for sure she was gone then."

5.2.2 Description of Near Misses from Roundtables

The near miss incidents discussed in the three roundtable sessions are summarized below.

5.2.2.1 Roundtable No. 1 – November 29, 2017

Two participants told of instances in which they felt that they were close to capsizing. In both cases, operators' practices were the primary cause of the "near miss." In the first instance, the participant said he was in shallow water. He had ended up in rougher weather than he had anticipated because he had not checked the forecast. As he attempted to turn the vessel, a large angle of heel ensued before it returned upright. The participant stated that he should not have been in the area in that particular vessel and he should have followed the forecast to avoid the rough seas.

The second incident occurred when a different participant was steaming with tubs full of fish on deck. With an increased center of gravity, the vessel experienced a large angle of heel before it returned upright and the crew were able to make it to port. The participant acknowledged that the tubs should have been stored in the hold of the vessel and ensured that he did so for future trips.

Both incidents have been included in Table 13. These incidents are additional examples of operator's practice being the primary cause of a near capsizing event. Both participants said the events were isolated incidents. The group said that near miss events are becoming less frequent because of the quota system in place. With a quota system, operators do not need to take as great of a risk to increase their overall catch. The importance of experience was brought up once more as a participant said that experienced operators take measures to reduce the likelihood of a near miss incident occurring. Finally, participants discussed the cod fishery. It was agreed that as cod returns to relevance in the Newfoundland and Labrador fishery, the current fleet of vessels will have trouble accommodating it. As a result, the number of near misses and capsizing events may increase.

5.2.2.2 Roundtable No. 2 – January 16, 2018

Multiple near misses involving participants were discussed. Participant 2 spoke of two separate incidents. In both incidents, improper dewatering of the catch led to the free surface effect. During the first "near miss," the vessel was half loaded with capelin. Because the equipment was not performing as it should, there was a large amount of water in the hold. The load acted as a free surface and reduced the vessel's stability. As a result, the vessel rolled to a large angle when it encountered a significant swell but the crew made it to port without capsizing. Participant 2's second near miss came when he was pumping capelin on a new vessel. There was a gap in the pen boards and the bottom of the hold and the load shifted during pumping operations. A large list occurred and the crew ceased operations and made it to port with a "heavy list." For both incidents, operator's practice was the primary cause according to participant 2 during this session.

Participant 4 also brought up a near miss in which he was involved in. A vessel that was being used for sealing was modified with a five-foot extension on the stern. The owner was confident it would be fine but did not get any stability work done and no inspections were performed. However, during operations the crew noticed the vessel was exhibiting abnormal behaviour that was originally attributed a malfunctioning autopilot. The vessel met a large swell that rolled the vessel to an angle that "threw" the crew from their bunks. A second swell caught the newly installed appendage and the vessel was put on its side for two minutes (as approximated by the participant). The vessel made it back to port. In this case, the impact of the appendage on the vessel's performance in rough weather was not considered. As such, it was an unsafe modification that was the primary cause of the near miss capsizing event. The three near misses are documented in Table 13.

5.2.2.3 Roundtable No. 3 – March 28, 2018

Participant 4 disclosed that he had been on a vessel that had come close to capsizing. The vessel was out in rough weather and rolled to an angle of approximately 45° when it was hit with a gust of wind close to 65 knots. After the large roll, the transmission failed and they had to be rescued. The participant said he had confidence in the vessel and that he never felt in any real danger. The cause of this near miss is operator practice as the vessel was operating in weather conditions it should not have been. The incident has been documented in Table 13.

5.3 Interviews

In order to gain a better understanding of operators' level of stability knowledge, one-on-one interviews were conducted. The interviews focused on vessel stability and the risk of capsizing. The outcomes of interviews were divided into critical categories pertaining to vessel stability, as described below.

1. Determining if a Vessel is Stable or Unstable

One of the basic indicators of stability is how a stable vessel "feels" compared to an unstable vessel. A vessel with a high metacentric height (a high initial stability) will feel "stiff" and respond quickly to disturbances. Accelerations are high and a vessel that has an excessive metacentric height will be uncomfortable. On the other hand, a vessel with low initial stability will feel “tender.” It will respond slowly to disturbances exhibiting low acceleration and feels comfortable.

While a vessel’s metacentric height does not describe the entire range of its stability, it is an important indicator of the risk of a vessel capsizing. It is important that operators are aware of the relationship between how a vessel responds to the sea and its stability. Without this basic understanding, it can be difficult for operators to make appropriate decisions regarding stability and capsizing.

2. Stability books

Operators were asked whether they had a stability book and, if they did, did they know how to use it and find it useful.

3. Maintaining a Stable Vessel

This question aimed to identify what operators perceived as best practices in regards to stability during operations. Operators’ actions while fishing are an important indicator of their understanding of stability. Understanding these actions can provide insight into whether or not operators are putting themselves in high-risk situations. This portion of the discussion can also indicate if there are any important best practices that operators are not aware of or if there are any dangerous practices that are common amongst participants.

4. Risk of Capsizing

Interview participants were asked what they felt posed the largest risk to capsizing a vessel during operations. Operators indicating what they perceive as the most significant risk can help to clarify their understanding of stability and what factors can make their vessel more susceptible to capsizing. Operators were also asked if they identified capsizing as a major risk. It is important to evaluate the awareness of operators to the risk of capsizing. Without sufficient recognition of the risk that capsizing poses, an operator may under-value decisions or actions that make their vessel more susceptible to capsizing.

5. Best ways to Reduce Capsizing

Finally, operators were asked what they felt was the best way to reduce capsizing risk. Specifically, participants were asked if the felt stricter regulations or increased education would be effective ways to reduce capsizing. Participants were asked if they would be open to additional stability training.

The interviews are summarized in the sections below. Participants that have received formal stability training are discussed in 5.3.1 and those without any formal stability training are discussed in 5.3.2. Interview participants are listed in Table 14. Operators with formal stability training are highlighted in red, while those without are in blue. Those fishing furthest away from St. John’s are highlighted in red, as are those with the least amount of experience. Distance from St. John’s was tracked as a potential proxy variable to measure the proximity to, or ease of availability of, stability training.

	Participant Number	Years Experience	Vessel Length (feet)	Distance from St. John's (km)[1]	Formal Stability Training
Interviews	1	27	60	91	Yes
	2	38	65	938	Yes
	3	33	57	106	Yes
	4	25	65	90	Yes
	5	38	65	938	Yes
	6	52	45	133	No
	7	40	65	420	Yes
	8	26	70	90	Yes
	9	14	50	131	Yes
	10	40	35	131	No
	11	55	40	131	No
	12	35	35	163	No
	13	40	39	130	No
	14	32	39	130	No
	15	30	40	85	No
	16	50	35	85	No
1) Driving distance to participant's residence per Google Maps					

Table 14: Interview Participants

5.3.1 Participants with Formal Stability Training

Participants who completed a Fishing Master First, Second, or Third Class ticket (or a Fourth Class ticket after 2007) are considered to have received formal stability training. Among other requirements, participants must pass a test that covers basic stability principles. The responses of participants to the categories listed in section 5.3 are summarized below.

1. Determining if a Vessel is Stable or Unstable

All participants who had received formal training were aware that an unstable vessel is "tender" and a stable vessel is "stiff." When asked how they could determine if a vessel was stable, most participants responded that the vessel's "feel" was an important indicator of a vessel's stability. During the ongoing discussion, all participants in this group confirmed that they were aware of the relationship between comfort and stability. Some participants specifically cited the term “metacentric height” or “GM” and possessed a sound understanding of the concept of initial stability.

Five of the eight participants explicitly stated that experience on the vessel was necessary to make safe decisions that ensure vessel stability. In other words, experience aboard a vessel is necessary to determine if it is stable or not. While opinions on stability books varied (see below), Participant 1 was the only operator said that stability analysis could be used to determine if a vessel was stable. The rest of the group that was interviewed did not rely on stability analysis to assess a vessel’s stability. Even Participant 1 stressed that while stability assessment was important, operators’ decisions and practices could not be underestimated.

2. Stability Books

Six of the eight participants who were interviewed that had formal stability training also had stability books for their vessel. However, opinions on the usefulness of stability books within those six operators varied greatly. Three operators felt that stability books were beneficial and useful. Participant 1, Participant 7, and Participant 8 were able to use and refer to stability books. Participant 1 went so far as to say, “Every boat should have a stability book.” As discussed previously, this participant felt that a stability assessment was a suitable way to assess a vessel’s stability. Participant 7 and Participant 8 gave less credence to stability books, but still felt they served a purpose. Participant 8 said that he referred to a vessel’s stability book when he did not have experience on that vessel.

In contrast, Participant 3, Participant 4, and Participant 9 did not refer to stability books or feel they were overly useful. These participants had stability books only to meet regulatory requirements. The stability work performed on the vessel had negligible influence on these operators' practices.

The two participants who did not have a stability book were Participant 2 and Participant 5. Participant 2 did say that stability books can provide some additional assurance. Participant 5 was the most against stability books within the group and stated, "Stability books are good for nothing."

3. Maintaining a Stable Vessel

Operators' responses to this question displayed a strong understanding of stability. The answers generally reflected actions that are important to take in order to avoid capsizing. Participants were not limited to a single response or the "most important" action to take in order to maintain a stable vessel; participants were allowed to provide as many answers to this question as they wanted. The responses to the question are summarized in Table 15.

Participant	Avoid Overloading	Avoid a High Center of Gravity	Avoid Shifting Loads	Avoid F.S.E.	Avoid Bad Weather	Use Stabalizers
1		✓	✓			
2	✓	✓		✓		
3		✓				
4				✓		
5	✓		✓			
7				✓		
8			✓	✓		
9			✓			

Table 15: Actions Cited as Important to Maintaining a Stable Vessel – Operators with Formal Stability Training

Avoiding the free surface effect was the most common response to this question, cited by four of the eight participants. Participant 7, who also participated in the second roundtable session, was quoted in the roundtable session as saying, "Free surface is the killer." During the interview, Participant 7 elaborated and said that if the weather is fine, there are many times he will load a vessel such that it has negative freeboard (i.e. the waterline is above the weather deck and below the top of the sheer strake). He explained that he takes proper precautions to ensure that the vessel is watertight and is confident he will not take on shipped water. Participant 8 also stressed the importance of ensuring that the vessel is watertight to avoid down-flooding.

Proper loading of the vessel was also a common response. This came in the form of overloading to ensure sufficient freeboard and/or keeping weights low to maintain a low center of gravity. The only conflicting remark came from Participant 7 who admitted that he overloads his vessel when he feels the risk is sufficiently low. Finally, avoiding shifting loads was the response of three operators. It was explained that on deck it is important to strap gear down, while in the holds it is important to use pen boards that are in good shape.

4. Risk of Capsizing

Responses to this question typically reflected what actions operators took to maintain stability on a vessel. Participant 1 felt that small scale design changes posed a significant risk to vessel capsizing. The example he gave reflected his response to the previous question, as he said many operators remove concrete ballast from their vessels, thus increasing the center of gravity. Participant 3's response was similar as he cited icing as having the potential to increase a vessel's center of gravity.

Participant 4 was the only operator to respond with extreme weather posing a significant risk of capsizing. Participant 9 was the only operator who cited the type of species being caught posing the most significant risk to a vessel capsizing. He said that sea cucumbers are most worrisome for him because it is difficult to prevent them from shifting in a vessel's hold.

Operators were asked to provide a general assessment of the risk they felt capsizing posed to them. It was clear that all participants were well aware of the risk posed to their lives due to capsizing. This was reflected in answers to the third and fourth questions. In general, however, participants felt well equipped to avoid capsizing because of their understanding of vessel stability. From their formal stability training, participants were aware of the risk of capsizing and best practices to take to minimize the risk of capsizing.

5. Best ways to Reduce Capsizing

There was unanimous agreement amongst the participants that improved education and awareness would be beneficial to the fishing community to reduce capsizing. Participants 4 and 8 specifically said that the stability training they received was useful. Participant 8 said that operators in NL on smaller vessels who are not required to participate in formal training may be lacking in this area. This idea was repeated in interviews with Participants 1, 2, 3, and 7. All felt that operators without Fishing Master Class tickets 3 or less were at a greater risk of capsizing because they lacked a sufficient understanding of vessel stability.

Participants were less receptive to the idea of stricter regulations that would require stability books on all vessels. Participants 1 and 4 felt that stricter regulations would provide some benefit because lack of regulations for smaller vessels can lead to poor design. However, the consensus amongst participants was that stability books are not likely to have a considerable effect on fishing vessel safety because they may not influence the decisions operators make while fishing. This sentiment is reflected by Participant 3 who stated, “If you don’t know how to use [a stability book], it’s no use to you.”

5.3.2 Participants with no Formal Stability Training

Operators with no formal stability training were posed the same questions as those who had received formal stability training. Members of this group were operators who had not received a Fishing Masters Class 3 ticket or higher or no equivalent training. There were a total of eight interviewees who had not received formal stability training.

1. Determining if a Vessel is Stable or Unstable

All participants referred to experience on a vessel as being the most reliable way to determine a vessel’s stability. Participant 11 was the only participant who felt that if a vessel had stability work performed it was inherently stable. Participant 15 and 16 both said that a vessel’s stability characteristics can be determined by comparing a vessel’s draft with the height of the vessel. Both participants felt that if the vessel had a shallow draft compared to its height, it was more susceptible to capsizing. This belief alludes to the idea that a vessel with a high center of gravity has poor stability characteristics and the operators based their assessment of a vessel’s stability on its appearance. This idea was also brought up by Participant 6. He stated that he was able to assess a vessel’s stability based on its dimensions.

Of the eight participants in this group, only Participant 12 referred to a vessel’s roll period as being indicative of its stability. Participant 12 said that if a vessel rolls out too far, it is unstable. Although he did not explicitly state the relationship between stability and comfort, it was apparent that this operator understood that a tender vessel is more susceptible to capsizing than a stiff vessel.

No other participant in this group referred to the stability of a stiff versus tender vessel. While no participant explicitly stated that a comfortable vessel implies stability, there were comments made that suggested this may be the case. For example, Participant 6 recalled a near miss when he described the vessel as being in “good shape” because prior to the incident it felt comfortable on the water and did not move much. Another example of a similar attitude was Participant 16. He complained that many vessels today are unstable because they are designed to optimize carrying capacity instead of comfort.

2. Stability Books

Participant 12 was the only participant who had a stability book, but he admitted that he does not use it. Most participants were generally indifferent on the subject of stability books and inclining tests. Participant 6 said that while a stability assessment would not hurt, it alone is not sufficient to ensure that a vessel does not capsize. This sentiment was repeated by Participant 13, who said that most accidents can be attributed to human error as opposed to vessel design.

Participants 15 and 16 both felt that stricter regulations on design need to be implemented for newer vessels, and stability analysis should be performed to ensure that these vessels meet design standards. Both operators stated that newer vessels are more likely to capsize because they are poorly designed by naval architects who lack experience. Participants 15 and 16 both strongly felt that the main reasons fishing vessels capsized was because of poor vessel design.

3. Maintaining a Stable Vessel

Although operators in this group did not have formal stability training, their responses to this question indicate that they take appropriate actions to avoid capsizing via causes highlighted in section 5.1. Actions taken by each participant are listed in Table 16.

Participant	Avoid Overloading	Avoid a High Center of Gravity	Avoid Shifting Loads	Avoid F.S.E.	Avoid Bad Weather	Use Stabalizers
6			✓	✓		
10			✓			
11		✓	✓			
12			✓			
13			✓		✓	✓
14			✓		✓	✓
15	✓		✓			
16	✓		✓	✓		

Table 16: Actions Cited as Important to Maintaining a Stable Vessel – Operators without Formal Stability Training

The most noticeable discrepancy in this group of participants and the group with stability training was that every operator without stability training brought up the impact that a shifting load has on stability. Because operating a smaller vessel does often not require any stability training, this response was not surprising. A smaller vessel is more likely to be impacted by a shifting load than a larger vessel. Therefore, it is likely of greater concern to the group of interviewees that operate smaller vessels.

This group also had two participants say avoiding harsh weather and using stabilizers as important ways to maintain stability. Neither of these responses was brought up by operators with stability training. Wind and waves can pose more of a risk to a smaller vessel, so operators without stability training on smaller vessels are more likely avoid rough weather.

Avoiding a high center of gravity and free surface were only mentioned once and twice, respectively. While operators may not have explicitly stated the effect a center of gravity has on stability, it was brought up as a concern on multiple occasions during other portions of the interviews. Specifically, Participants 6, 15, and 16 all said that vessels that appear top heavy are likely unstable. Similar sentiments were brought up in regards to the free surface effect. While operators may not have an exact understanding of the impact of a free surface on stability, they are aware that leaks are detrimental to safe operations.

4. Risk of Capsizing

Much like the group of operators with formal stability training, answers as to what posed the most significant risk of capsizing generally reflected the actions the operators took to maintain stability. Fish species was brought up in this portion of the interview. Participant 12 discussed sea cucumbers posing a risk of capsizing because of the possibility of shifting loads, while Participant 13 mentioned pelagic species. Operators also remarked that rough weather and leaks pose a risk to their vessel capsizing.

All participants agreed to meet to discuss the risk of capsizing. Therefore, there is little doubt that to a certain extent, they are all aware that there is some degree of risk regarding the loss of their life and/or vessel due to capsizing. However, among operators with no formal stability training, the perception of this risk varied greatly. Furthermore, this group of operators generally regarded the risk of capsizing as being much less severe than the group of operators with some form of stability training. Several operators made comments that suggest that they feel capsizing poses little risk. Others made comments which reflected an impression of unconditional safety, provided certain criteria are met.

Participant 10[2], when prompted to assess the risk he felt capsizing posed, responded with "No risk." This is an example of a lack of operator awareness. Participants 13 and 14's opinions of capsizing were not as nonchalant as Participant 10, but both stated that they did not feel that capsizing posed a significant risk. With regards to capsizing, Participant 14 said that he "…doesn't think about it much." Participants 13 and 14 appeared as capable operators but it is apparent that they lacked awareness of the risk posed by capsizing.

In other cases, operators without formal stability training gave the impression that the risk of a vessel capsizing is next-to-negligible if that vessel meets certain design parameters. For example, Participant 6 opined that it was primarily undecked vessels that should be concerned with capsizing because they much more likely to become swamped than a decked vessel. Similar sentiments were expressed by Participant 11. He stated that if a vessel had an inclining test performed, it had suitable stability characteristics and therefore there was little risk of capsizing. Participants 15 and 16 also felt that if a vessel was designed properly, an operator did not have to worry about a capsizing event occurring, and that capsizing of modern vessel was due, in large part, to poor engineering and naval architecture decisions.

5. Best ways to Reduce Capsizing

While no participant could be said to be overly enthusiastic about an educational program, the general consensus was that any training that could improve safety would have some benefit. Participants 13 and 14 said they would be open to additional training in the

[2] Participant 10 was only a crew member on his vessel, not a skipper.

form of a seminar, as did Participant 11. However, within this group there was an emphasis placed on the need for stricter regulations on vessel design. Participants 15 and 16 were the most adamant on this point. Both felt that the primary cause of vessels capsizing was due to poor design. They felt that the most effective way to reduce capsizing events would be to place stricter regulations on the vessel design and ensure that they meet stability criteria.

The effect that the Department of Fisheries and Oceans' (DFO) regulations have on operator safety was also raised. Participants 6, 13, 15, and 16 all brought up sinking of the *Pop's Pride*, an undecked vessel that sank off St. John's while retrieving nets in 2016 (Transportation Safety Board of Canada, 2016). All of these participants said that the vessel should not have been on the water that day due to rough weather, but had to retrieve nets in order to avoid a fine.

5.3.3 Summary of Interviews

Interviewing fishing vessel operators was an effective means of providing an estimation of their understanding of stability. The most significant observation from this portion of the research was the discrepancy in the level of knowledge between operators that have received formal training and those that have not. To some degree, this also reflects a divide between those who work on large SFVs and those who work on smaller SFVs. Operators who had received stability training were well versed in basic stability principles. The most evident reflection of training was that these operators were all aware that a tender, comfortable vessel is more likely to capsize than a stiff vessel. Among operators without training, there was little evidence to suggest that they understood this relationship.

All operators interviewed (training or no training) provided examples of good practices they undertake to maintain stability of their vessel. This suggests that even without training, operators tend to make sound decisions based on their experience. In particular, operators without stability training understood the importance of avoiding shifting loads, leaks, and a high center of gravity. This knowledge can be attributed to intuition and experience as opposed to a formal understanding of vessel stability. In contrast, operators with training have supplemented their experience with a technical understanding of the principles of stability.

Operators without stability training were generally less aware of the risk of capsizing. The most obvious disregard of the risk of a vessel capsizing from untrained interviewees came from Participant 10, who felt that capsizing posed “no risk.” In addition to a discrepancy in the concern between the two groups, operators without training made comments that suggest they lack proper awareness of the impact their actions can have on their vessel’s stability. Participant 6’s comments in regards to undecked vessels is an example of this. While undecked vessels are certainly more susceptible to shipped water, the majority of capsizing events analyzed in section 5.1 occurred on decked fishing vessels. Another example of an untrained participant not recognizing the risk of capsize was Participant 11, who suggested that meeting stability criteria implied a vessel was stable. Finally, comments by Participants 15 and 16 further reinforce the idea that untrained operators may not recognize the risk posed by capsizing. Their comments regarding the relationship between vessel design and the likelihood of capsizing suggest that they feel if an operator is confident in their vessel’s design, they may not pay the attention they should to the impact their actions have on vessel stability.

The perception of low risk, combined with an inability to determine when their vessel has become susceptible to capsizing, puts operators without training at a greater likelihood to capsize. This illustrates the positive impact that technical training has on the NL fishing community. It further suggests that expanding stability regulations to encompass smaller vessels may not be as effective as training in preventing capsizing. A lack of understanding of stability and awareness of the risk posed by capsizing would still be present amongst operators without formal stability training.

Comments from participants 6, 11, 15, and 16 provide evidence that untrained operators place high reliance on stability assessments. This reliance introduces the potential for an operator to neglect best operating practices because they have the impression that stability work ensures that their vessel is unconditionally safe. It is important that operators realize the consequences of their actions and the role they play when it comes to maintaining a stable vessel.

5.4 Roundtables

The final portion of research was roundtable discussions with fishing vessel operators. There were three roundtables conducted, with all participants recruited through the NLFHSA. To encourage open and candid discussions, the roundtables were not recorded. Instead, extensive notes were taken during the discussions. The first two roundtables were chaired by a representative from the NLFHSA and notes were taken by the project investigator. The third roundtable was simultaneously chaired and noted by the project investigator.

In the following sections, summaries of each roundtable are provided. A detailed discussion on each of the roundtables can be found in Appendix C. In Appendix C, questions posed to the participants by the chairperson are numbered and a summary of the discussion amongst the group for each question is provided.

5.4.1 Roundtable No. 1 – November 29, 2017

The first roundtable was held in St. John's on November 29, 2017. In addition to the chairperson and investigator, there were five participants. All participants were experienced operators who were open to the idea of joining the roundtable when approached by the NLFHSA. Throughout the discussion, all members contributed to the conversation. In general, there was a consensus amongst participants that stability is an important consideration for safe operation of a fishing vessel. As per Table 17, four participants had formal stability training while one did not.

	Participant Number	Years Experience	Vessel Length (feet)	Distance from St. John's (km)[1]	Formal Stability Training
Roundtable 1	1	35	45	286	Yes
	2	52	39	13	No
	3	25	65	108	Yes
	4	42	39	90	Yes
	5	30	65	11	Yes
1) Driving distance to participant's residence per Google Maps					

Table 17: Roundtable No. 1 Participants

The participants for the first roundtable were all experienced operators. This was reflected in a strong understanding of stability among the group's participants. While the formal training varied, everyone was aware of best practices. Unsafe loading and the free surface effect's impact on vessel stability were well understood. Although some participants did not know how to use stability books (or felt they were not useful), all participants displayed a sound understanding of best practices. Experience was often brought up as an important aspect of maintaining a stable vessel. In this roundtable there were no examples of an operator not understanding basic principles of stability or the risk associated with capsizing. There was, however, an operator with no formal stability training. This is an example of an operator without formal training possessing sufficient knowledge to make safe and informed decisions.

An important consideration brought up in this roundtable was the effect that the species being fished has on the stability of a vessel. While regulations are stricter for pelagic species, TSB reports do not attribute the species type as having a significant impact on capsizing events. Different species' impact on stability is an important consideration for future work.

Finally, the consensus among the group was that capsizing is a significant hazard and the best way to reduce the frequency of capsizing events is through education and awareness. No operator felt that stricter regulations or requiring all vessels to carry stability books would see a significant reduction of vessels capsizing. No participant mentioned overloading as a significant risk of capsizing, although this is repeatedly cited as a contributing cause of capsizing in TSB reports.

5.4.2 Roundtable No. 2 – January 16, 2018

The second roundtable was held in St. John's on January 16, 2018. Like the first roundtable, it was chaired by a representative from the NLFHSA. Participants were from different parts of Newfoundland and Labrador and were in St. John's to attend a Marine First Aid Recertification. Following a day of meetings, seven of the program's attendees agreed to stay to participate in the roundtable. Compared to the first roundtable, members were initially tentative and had to be encouraged by the chairperson. However, as the roundtable proceeded, most participants contributed to the discussion.

Like the first roundtable, all participants were experienced operators. As per Table 18, everyone had at least 30 years of experience. However, this session had a much wider range of demographic than the first. The second roundtable included participants from outside of St. John’s or surrounding areas and the size of the vessels ranged from a 22’ open boat to 64’11” fishing vessels. Only one member of the group had received formal stability training.

	Participant Number	Years Experience	Vessel Length (feet)	Distance from St. John's (km)[1]	Formal Stability Training
Roundtable 2	1	30	40	165	No
	2	40	65	420	Yes
	3	35	45	651	No
	4	35	35	651	No
	5	43	22	770	No
	6	30	35	234	No
	7	30	40	290	No

1) Driving distance to participant's residence per Google Maps

Table 18: Roundtable No. 2 Participants

With a wider demographic, the second roundtable presented different conclusions than the first. While all participants had extensive experience, the amount of formal training varied greatly. In this session, there was an observable discrepancy in the stability knowledge among the formally trained and untrained participants in the group. The most obvious example of this was when Participant 6 felt their vessel had poor stability characteristics because it was uncomfortable. Participant 7 corrected Participant 6 during the roundtable. This exchange involved two operators that had not received any formal stability training. However, the level of understanding of basic stability principles was quite different. Furthermore, only Participant 2 of this roundtable had formal stability training, but most of the group agreed with Participant 7's statement that an uncomfortable and stiff vessel likely had sound stability characteristics.

Another relevant example was Participant 4 not knowing the effect of modifying a vessel deck would have on the vessel's center of gravity and stability. The fact that Participant 4 inquired about a seemingly basic principle of vessel stability suggests a lack of understanding in that area. Finally, Participant 5, who operated a small open boat, contributed little during the (approximately) two-hour discussion. The three operators mentioned above did not have formal stability training.

However, Participant 7, also with no formal stability training, displayed awareness of basic stability principles. This finding is attributed primarily to his statement that an uncomfortable vessel is likely stable. The reception to this response by other members without stability training is an example of those members displaying awareness despite a lack of training. However, Participant 2, the only member with stability training, demonstrated the strongest understanding of vessel stability amongst the group.

Another important takeaway from the second roundtable was what the operators felt posed the most significant risk to a vessel capsizing. Based primarily on Participant 2's testimony, the free surface effect is of the greatest concern in regards to vessel stability. Lack of vessel maintenance, which can result in leaks that accumulate in a free surface, was recognized by the group as being detrimental to vessel safety. Like the first session, the type of species was considered important amongst the group. Sea cucumbers were identified as posing the greatest risk.

In the second roundtable, the group's reception to the idea of stability training was positive. There were no members who were opposed to the idea or felt that additional training would not be of use. An important consideration for any future educational program is the knowledge discrepancy between operators who have received formal training and those who have not.

5.4.3 Roundtable No. 3 – March 28, 2018

The third roundtable session took place in Lumsden, Newfoundland and Labrador. Following a day of Marine Emergency Duties (MED) training, the NLFHSA arranged for four operators to stay behind to take part in the roundtable. The motivation for the final roundtable was to meet with operators who lived outside of the St. John's region and fished on vessels less than 35 feet long. With this demographic, it was possible to assess the stability knowledge of operators who had received little to no formal training. This session was both chaired and noted by the project investigator.

As per Table 19, the participants had less experience than the previous two sessions; the most experienced operator had 18 years of experience and the least experienced operator had two. No participant had any formal training that would have covered stability. Participants were generally reluctant to contribute. This may have been because the session was not chaired by a NLFHSA representative, or it may have reflected the level of stability knowledge amongst the group.

	Participant Number	Years Experience	Vessel Length (feet)	Distance from St. John's (km)[1]	Formal Stability Training
Roundtable 3	1	2	35	388	No
	2	14	35	378	No
	3	18	19	388	No
	4	5	35	388	No
1) Driving distance to participant's residence per Google Maps					

Table 19: Roundtable No. 3 Participants

Roundtable No. 3 was exclusively comprised of operators with no formal stability training. It was evident from responses that the group lacked an understanding of basic principles of vessel stability. There was no evidence that any member of the group was aware of the relationship between a vessel's roll motion and stability. Participant 4, in particular, stated that a stable vessel is comfortable in rough waters. This roundtable's participants were also the most hesitant to respond to the questions and contribute. This may have reflected an unwillingness to partake in the discussion or have been further evidence of a lack of stability knowledge.

The group were generally not concerned with capsizing. Participant 2 explicitly stated that he felt capsizing posed little risk. It was obvious from this portion of the conversation that the group did not recognize capsizing as the significant risk that many participants of the other focus groups did. Their perception of risk was even more surprising given that the group was familiar with the loss of the *Miss Cat Harbour* due to capsizing (refer to Appendix C for more details on this part of the discussion). The fact that participants were not aware of the actual cause of the incident indicates that the members had not had an opportunity to learn from a tragedy that occurred to one of their peers. This supports the argument that the group does not recognize the risk that capsizing presents.

The group was open to an education program, however. Members provided their opinion on the best way to implement an awareness program aimed at improving stability knowledge of operators with no formal training. This is an important consideration for future work.

5.4.4 Summary of Roundtables

The roundtables provided valuable insight into operators understanding of stability. The most important findings are discussed below.

1. Role of Formal Training

Formal training had a significant impact on an individual's knowledge of stability. For certain vessels, operators are not required to undergo any formal stability training (see section 3.2). There was a discrepancy in the level of stability knowledge in those that had received stability training and those that had not. Many of the participants without stability training showed less understanding of the basic principles of stability in comparison with those that had received training. Untrained participants were generally unaware of the relationship between roll characteristics and stability (Roundtable No. 2 – Participant 6; Roundtable 3). In contrast, participants with formal training were aware of the relationship. Those participants with formal training also brought up the relevance of the free surface effect throughout the sessions. There was little to indicate that operators of smaller vessels were as aware of the risks posed by having a free surface aboard a vessel.

There were, however, exceptions to this trend. During the first roundtable, Participant 2 did not have formal stability training yet made no response that suggested he was any less knowledgeable than other members of the group concerning stability. Roundtable No.2

provided further examples of operators without training showing an understanding of basic stability principles. Participant 7 correctly pointed out that an uncomfortable vessel is more likely to be stable than a comfortable vessel, and this statement was met with a positive response by other members of the group without stability training.

Among operators with formal stability training, there were none who made statements to suggest that, despite their training, they lacked an understanding of vessel stability. All participants within this group possessed a strong knowledge of stability and awareness of the risk due to capsizing. While some accurate statements of operators without stability training demonstrated an understanding of stability, there was generally a strong correlation between stability knowledge and the amount of training an operator received. Those with training demonstrated a greater understanding and awareness than those who did not.

It is probable that for operators without stability training, their awareness and knowledge can be attributed to experience. The operators without training that displayed strong awareness all had at least 30 years of experience. This fact suggests that experience can play a role in regards to safe operation of a fishing vessel and maintaining stability.

2. Risks Posed to Operators in Regards to Capsizing

There were common factors identified throughout the roundtables that operators felt posed a risk to a vessel's stability. The type of species being caught was emphasized in the first two sessions. In particular, sea cucumber was of great concern for many operators because of its ability to act as a shifting load. It was also well understood that vessels fishing for pelagic species are more susceptible to capsizing because of the viscosity of pelagic species in bulk. It should be noted that none of the participants of Roundtable No. 3 fished for pelagic species.

The free surface effect was also discussed extensively, especially in Roundtable No. 2. It was stated explicitly by a participant in that session that many operators do not understand the free surface effect. The fact that the free surface effect was not brought up by any participants in Roundtable No. 3 supports this argument. The same participant stated his opinion that free surfaces on fishing vessels are the primary cause in the majority of capsizing incidents. Other participants discussed dangers due to down-flooding via shipped water or leaks.

Participants of all sessions understood that increasing a vessel's top weight makes that vessel more susceptible to capsizing. As this concept is perhaps the most intuitive, it is not surprising that it was well understood. Overloading was rarely mentioned as a significant contributor to capsizing events. Overloading, however, was prevalent in the investigation reports and was often identified as a primary cause. It was expected by the author that it would be taken into greater consideration among participants than it was.

3. Operator Experience Versus Stability Assessment

While only some participants felt that inclining tests and stability books were useful, the consensus was that operator experience was the best prevention against capsizing. This supports the hypothesis that the most effective way to reduce capsizing is to educate operators on best practices. This will allow operators who may not have as much experience to still make informed decisions in regards to the stability of their vessel.

Further, this would give experienced operators with no formal training an improved understanding of vessel stability and a greater awareness to the risk of capsizing.

4. Openness to Education and Training

One of the most important conclusions of the roundtable sessions was participant openness to educational programs focusing on vessel stability. There was consensus amongst participants across all demographics that education is beneficial. Even those with little understanding of stability supported a program that would provide them with additional training. As this is the demographic that would likely benefit the most from an educational program, this response was encouraging. It was suggested in Roundtable No. 3 that a program consist of classroom sessions with an instructor.

6.0 Discussion

Results obtained from the research presented in section 5.0 are discussed in detail below. Identifying the primary causes of fishing vessel capsizing events was an important deliverable for this study. The results discussed in section 5.1.1 are revisited and commented on in section 6.6. Discussions with operators during interviews and roundtables provided an opportunity to explore the idea of near miss reporting in the fishing industry. While the development of a near miss reporting process was not a primary objective of the current research, the process is thought to offer promise. Interviews also provided an assessment of the understanding of vessel stability among operators in Newfoundland and Labrador. These findings are discussed and important trends are highlighted. Finally, the possible relationships between the primary causes of capsizing and operators' understanding of stability are established and examined.

6.1 Fatality Rates for Fishing Vessel Capsizing Events in Canada (2004-2017)

The trends of sinking/capsizing accidents were analyzed using Canada's TSB data from 2004-2017. Note that fatalities due to sinking and capsizing have been included in the same category. This is because there are inconsistencies in the TSB's database in regards to categorizing an accident as a "sinking" as opposed to "capsizing." However, because the causes of sinking and capsizing are often the same, and often both capsizing and sinking occur during the same incident, it is appropriate to include them in the same category. The data is available in Transport Canada's *Marine Occurrence* spreadsheet that the organization releases every month. The data includes all marine accidents in Canada from 2004 up to and including the respective month the data is released.

According to the TSB, of the 11,218 total marine accidents, 5,027 were fishing vessel accidents (44.8%). Further, there were 248 fatalities in the marine industry during this time period. Of the total number of fatalities, 152 occurred on fishing vessels, accounting for 61.3% of all fatalities.

As per Table 20, of the 5,027 accidents involving fishing vessels, only 219 were due to sinking/capsizing (4.4%). However, of the 152 fishing vessel fatalities listed by the TSB, a disproportionate number is attributed to sinking/capsizing. 70 fatalities were the result of fishing vessels sinking/capsizing, or 46.1% of all fishing vessel fatalities. The ratio of the number of fatalities due to sinking/capsizing and the number of sinking or capsizing events supports the statistics presented by Loughran et al. (2002).

Total Number of Accidents	11,218	Number of Fishing Vessel Accidents	5,027
Number of Fishing Vessel Accidents	5,027	Number of Fishing Vessel Stability Related Accidents	219
Percentage	44.8	Percentage	4.4
Total Number of Fatalities	248	Number of Fishing Vessel Fatalities	152
Total Number of Fishing Vessel Fatalities	152	Number of Fishing Vessel Stability Related Accident Fatalities	70
Percentage	61.3	Percentage	46.1

Table 20: Fishing Vessel Capsizes from TSB (2004-2017)

6.2 Capsizing Trends in Canada (2004-2017)

The same data used to examine fatality rates for capsizing events was also studied to identify trends in the number of capsize events. The number of capsizes and number of fatalities from capsizes were tabulated for each year. The results are presented in Table 21. Employment of fish harvesters in Canada over the same time period was also included.

Year	Employment	No. of Capsizings	No. of Capsizings/10,000 Operators Employed	No. of Fatalities	No. of Fatalities/10,000 Operators Employed
2004	53,770	22	4.1	13	2.4
2005	52,805	19	3.6	11	2.1
2006	51,677	22	4.3	6	1.2
2007	53,820	13	2.4	1	0.2
2008	52,107	23	4.4	10	1.9
2009	52,812	10	1.9	6	1.1
2010	45,069	15	3.3	1	0.2
2011	50,920	7	1.4	0	0.0
2012	49,609	12	2.4	1	0.2
2013	43,250	14	3.2	6	1.4
2014	45,904	20	4.4	2	0.4
2015	40,940	13	3.2	6	1.5
2016	42,507	19	4.5	6	1.4
2017	44,342	10	2.3	1	0.2
% Change Trendline	-22.7	-35.3	-13.7	-81.4	-68.5
Slope	-958	-0.5165	-0.0367	-0.5275	-0.0815
Intercept	55,724	19.516	3.5099	8.956	1.6292
Average	48538.0	15.6	3.2	5.0	1.0
Standard Deviation	4470.6	5.0	0.99	4.0	0.8
Coefficient of Variation	9.2	31.7	30.5	80.7	76.2

Table 21: Capsizes and Capsizing Fatalities in Canada (2004-2017)

The number of capsizes and the number of fatalities from capsizes each year were totalled to determine any observable trends. Capsizes – and fatalities from capsizes – are relatively rare. As expected from rare events, the number fluctuates greatly from year to year; for both sets of data there is a high coefficient of variation. While there is noise in the data, both events had decreasing trends from 2004 to 2017. See Figure 4 and Figure 5.

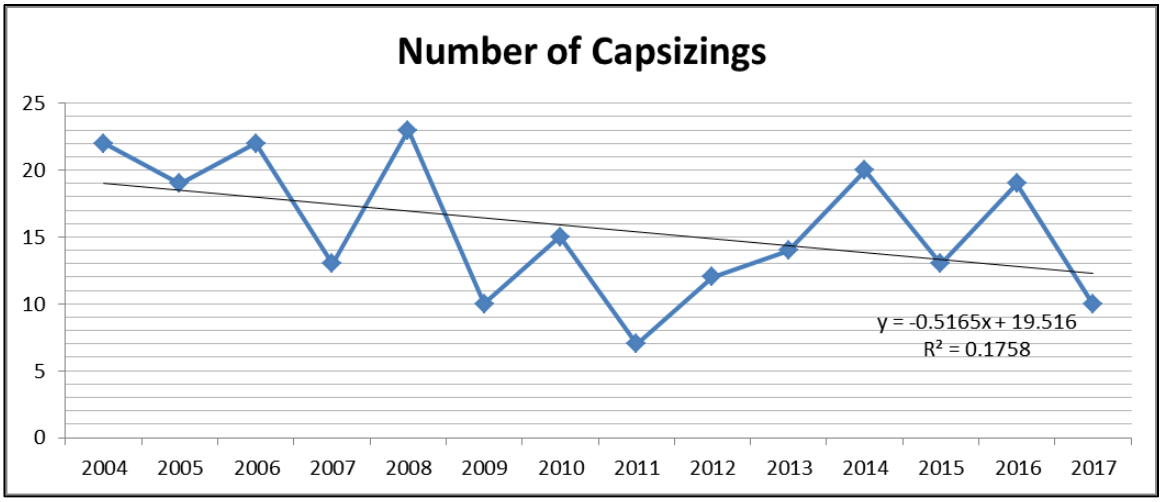

Figure 4: Capsizes in Canada from 2004 - 2017

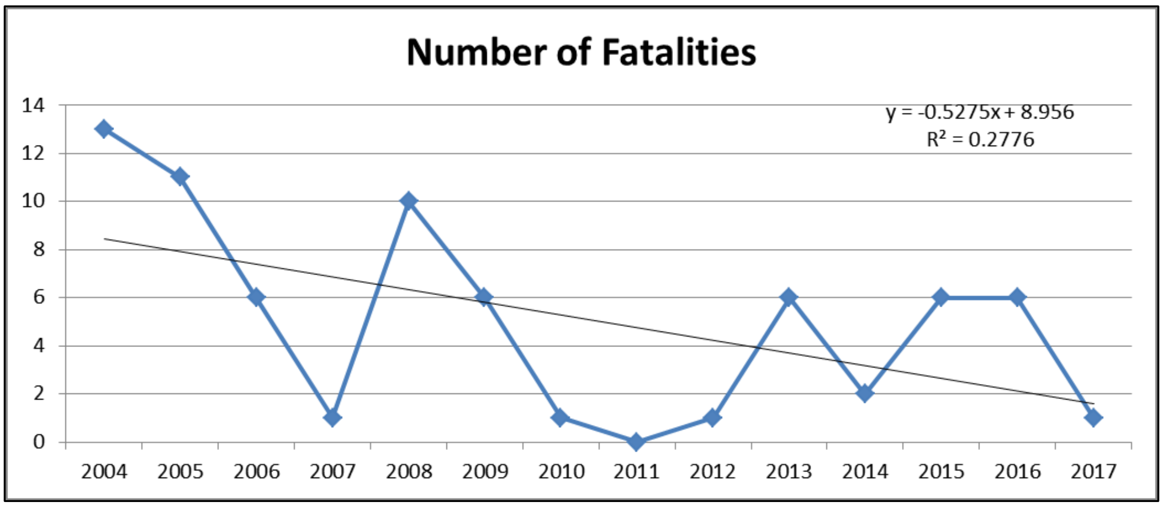

Figure 5: Capsizing Fatalities in Canada from 2004 – 2017

In order to determine a possible explanation for the reduction in capsizes and fatalities, employment statistics for fish harvesters was taken into account. The number of people employed as fish harvesters in a given year is the best parameter available to estimate operator exposure. The number of vessel hours spent operating would provide a better assessment of the average operator's true exposure but these statistics were not available. There was insufficient data available to accurately estimate the number of operator hours spent fishing for a given year. Therefore, it is assumed that the number of hours fishing per employed individual remains constant from year to year.

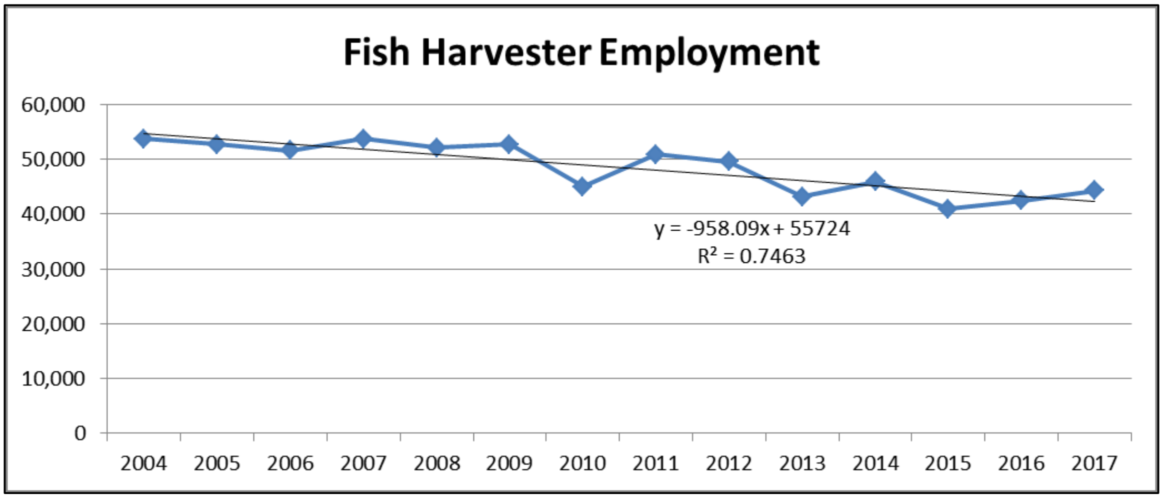

Figure 6: Fish Harvester Employment in Canada from 2004 – 2017

As seen in Figure 6, employment of operators in Canada has declined from 2004 to 2017. As reflected in the coefficient of determination (R^2), the employment statistics have less variation than capsizing and fatality data. This is expected given that the employment numbers are three orders of magnitude greater than the frequency of capsizing and fatalities.

The impact that employment/exposure has on the frequency of capsizing was assessed by calculating "Capsizing per 10,000 Operators Employed." This normalized the capsizing/fatality data to determine the correlation between the frequency of accidents and operator exposure. A trend line that is constant would suggest that the decrease in accidents directly corresponds to the reduction in exposure. However, as per Figure 7 and Figure 8, the normalized data still decreased from 2004 to 2017. The fact that the normalized data is decreasing suggests that the reduction in capsizing may be attributed to more than simply a reduction in exposure. However, the role of exposure's impact on accidents is still significant, as can be seen in Table 21. Specifically, the reduction in incidents as described in the trend line for the "No. of Capsizes" and "No. of Capsizes per 10,000 Operators

Employed" decreased from 32.5% to 12.5%[3]. Single linear regression analysis was performed to establish trend lines for each set of data.

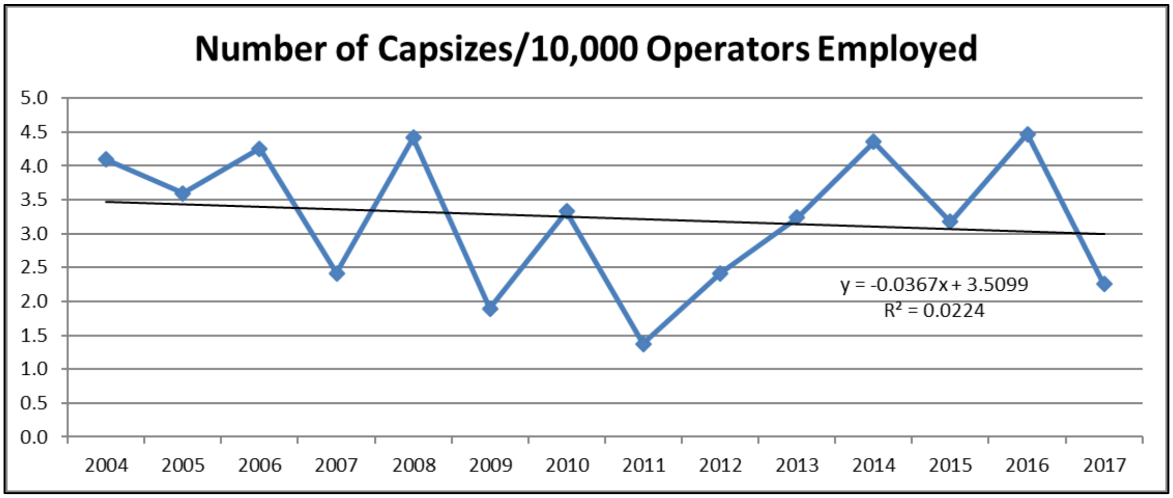

Figure 7: Capsizes/10,000 Operators Employed in Canada from 2004 - 2017

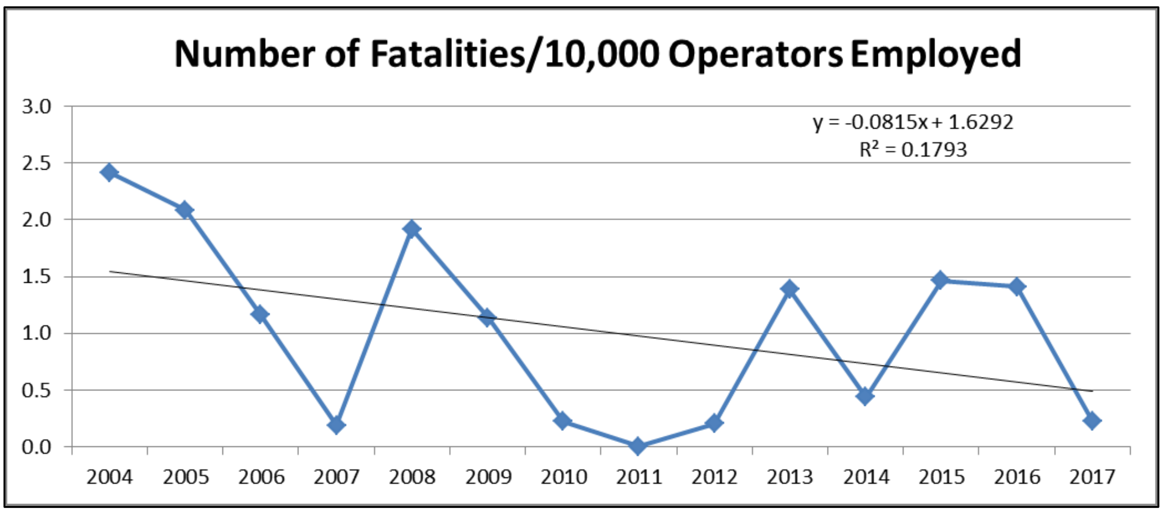

Figure 8: Capsizing Fatalities/10,000 Operators Employed in Canada from 2004 – 2017

6.2.1 Hypothesis Testing on the Slope of the Regression Line

In order to determine if the downward trend in Figure 7 is statistically significant, it was necessary to perform hypothesis testing on the slope of the regression line. This analysis quantifies the likelihood that the slope of the line is simply a result of noise in the

[3] From Figure 4, the value of the trend line in the year 2004 is 19.9. In 2017, the value is 12.8. This is a 32.5% reduction. The same exercise using the trend line from Figure 7 shows a 12.5% reduction from 2004 to 2017.

data over the years that sample data was available as opposed to an actual trend in capsizing events. A null hypothesis was established that stated the slope of the regression line was 0. If the probability of the slope being 0 given the observed slope in Figure 7 is less than 5%, the null hypothesis can be rejected. If this is the case, the alternative hypothesis, that the slope is less than zero, is assumed to be true. The results of the hypothesis test show that there is a 70% chance the slope of the regression line is statistically significant and not a result of fluctuations in the data. Details of the calculation are in Appendix D.

Given that capsizes are rare events, the sample size was relatively small, and there was a small coefficient of determination, the conclusions from the hypothesis test are not surprising. While the null hypothesis cannot be rejected with significant confidence, its result says that there is 70% likelihood that there exists a decreasing linear relationship between the number of capsizes in a given year and the respective year. Otherwise stated, it is likely that there is a trend in capsizes independent from operator exposure.

6.2.2 Possible Explanation for Trend – Training in Canada

The results from the hypothesis test suggest that there is a trend in capsize events that is independent of operator exposure. One possible account for this trend is formal stability training. As per section 3.2, since 2007, operators obtaining a Fishing Master Fourth Class certificate have to undergo formal stability training. The number of operators holding this certification is significant in Canada. Although exact statistics are unavailable, estimates can be made based on data available from the Department of Fisheries and Oceans (2016). From 2006 to 2008, approximately half of all fishing vessels registered in Canada were less than 35 feet, and approximately 40% were between 35 and 45 feet. Typically, these vessels are less than 100T and operate in coastal waters. Thus, the highest certification operators of these vessels are likely to have is a Fishing Master Fourth Class.

Given the distribution of vessel size in Canada, it is hypothesized that the majority of operators hold at most, a Fourth Class ticket. Alterations made to the training program in 2007 are therefore likely to have a significant impact on the likelihood of an operator understanding basic stability principles. It is suggested that this increase in the training requirements for operators obtaining a licence post 2007 is responsible, at least in part, to the trend that was observed in fishing vessel capsizes from 2004 to 2017.

6.3 Relationship between Vessel Size and Capsizing

The frequency of incidents of fishing vessels in five-foot length intervals was compared to determine if there was any trend relating vessel length to likelihood of capsizing. As per Figure 9, the probability of capsizing depends little on the size of the vessel. The drop off after 85 feet in length is likely due to the fact that 98% of fishing vessels worldwide are less than 24m (78.7 feet) in length (Lloyd’s Register Foundation, 2018). From the investigation reports studied, there was no definitive trend relating vessel size to the likelihood of capsizing.

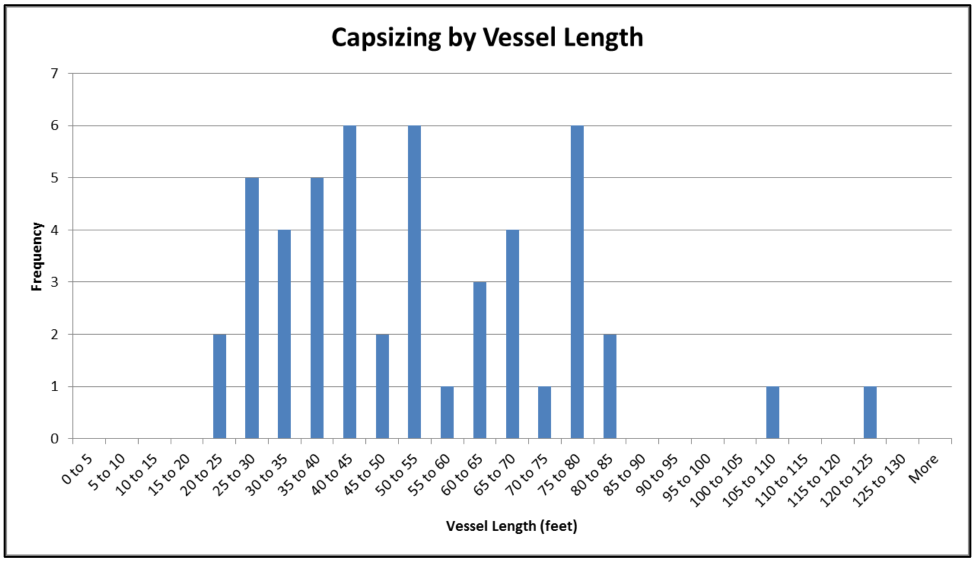

Figure 9: Capsizing by Vessel Length

6.4 Operator Stability Knowledge Trends

In order to identify any trends in operator stability knowledge, interview and roundtable participants were assigned a "Stability Knowledge Index" of -1, 0, or 1. The index attempted to quantify a participant's knowledge of stability and awareness of the risk of capsizing. A knowledge index of 1 represented a participant that showed a strong understanding of stability principles, while -1 represented a participant that displayed a lack of understanding. The primary indicator of an individual's stability knowledge was their awareness of the relationship between stability and a vessel's motions. Participants' perceptions of the risk of capsizing were also taken into account when assigning knowledge indices. This was a completely subjective exercise. There was no quantitative data collected to calculate knowledge indices. Stability indices for participants can be found in Table 22. The table's categories are explained in the following sections.

Participant	Experience/10 (years)	Vessel Length/10 (m)	Stability Training (yes/no)	Distance from St. John's	Stability Knowledge Index
1	2.7	1.83	1	91	1
2	3.8	1.98	1	938	1
3	3.3	1.74	1	106	1
4	2.5	1.98	1	90	1
5	3.8	1.98	1	938	1
6	5.2	1.37	0	133	0
7	4	1.98	1	420	1
8	2.6	2.13	1	90	1
9	1.4	1.52	1	131	0
10	4	1.07	0	131	-1
11	5.5	1.22	0	131	-1
12	3.5	1.07	0	163	0
13	4	1.19	0	130	0
14	3.2	1.19	0	130	0
15	3	1.22	0	85	-1
16	5	1.07	0	85	-1
17	3.5	1.37	1	286	1
18	5.2	1.19	0	13	1
19	2.5	1.98	1	108	1
20	4.2	1.19	1	90	1
21	3	1.98	1	11	1
22	3	1.22	0	165	0
23	3.5	1.37	0	651	0
24	3.5	1.07	0	651	-1
25	4.3	0.67	0	770	-1
26	3	1.07	0	234	-1
27	3	1.22	0	290	1
28	0.2	1.07	0	388	-1
29	1.4	1.07	0	378	-1
30	1.8	0.58	0	388	-1
31	0.5	1.07	0	388	-1

Table 22: Interview and Roundtable Participants Stability Knowledge Index

In order to identify trends to predict the likelihood of an operator possessing a strong understanding of stability, the stability knowledge indices were plotted against some of the other variables collected during the study.

6.4.1 Experience versus Stability Knowledge

The first analysis was of operator experience and stability knowledge. The two variables were plotted and a trend line was included. Operators' years of experience has been divided by 10 for clarity. The coefficient of determination of 0.027 in Figure 10 suggests that there is little correlation between operator experience and stability knowledge.

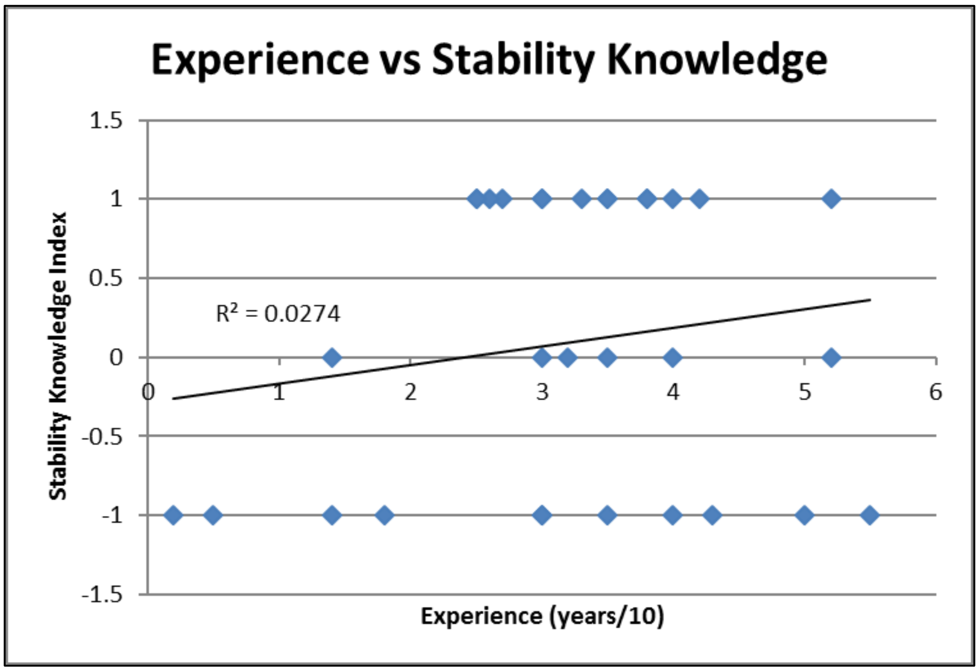

Figure 10: Experience vs Stability Knowledge

6.4.2 Vessel Length versus Stability Knowledge

The length of an operator's vessel was plotted against stability knowledge. As per Figure 11, the correlation coefficient of 0.535 is relatively high. This suggests that vessel length and stability knowledge are, at least somewhat, correlated. As per section 3.2, requirements for stability training are based largely on vessel length. Therefore, a correlation between vessel length and stability knowledge is expected.

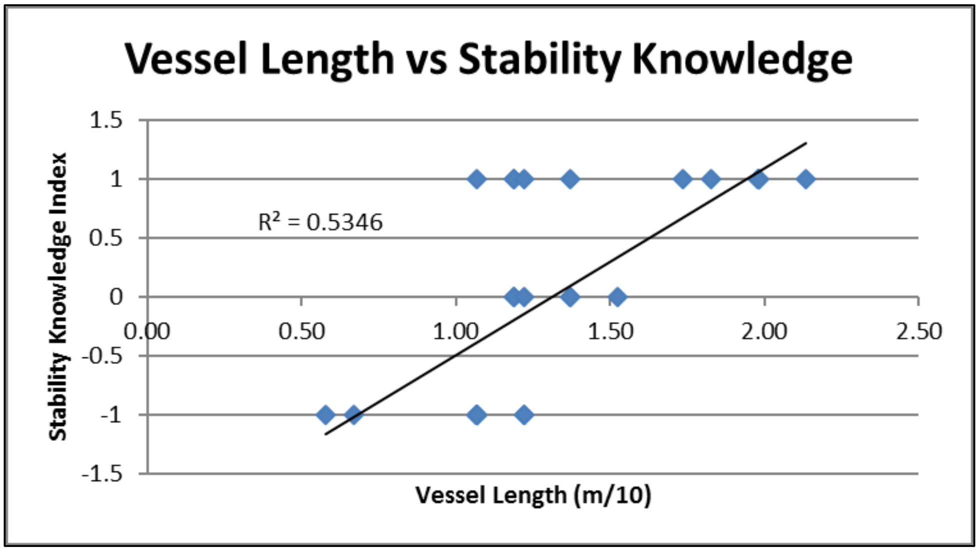

Figure 11: Vessel Length vs Stability Knowledge

6.4.3 Operator Training versus Stability Knowledge

The third variable that was analyzed was operator training. This variable was binary: an operator who had completed some form of stability training was assigned a value of 1 in the third column of Table 22 and an untrained operator was assigned a value of 0. There were six possible combinations of operator training and operator stability index, shown in Table 23. The table shows that there is a strong relationship between training and operator knowledge. 11 operators who did not have any stability training had stability indices of -1. Conversely, 11 operators who had stability training had indices of 1.

Stability Knowledge Index	Number of Operators without Training	Number of Operators with Training
-1	11	0
0	6	1
1	2	11

Table 23: Stability Knowledge Indices of Trained and Untrained Operators

The correlation between training and knowledge can also be seen by plotting the two variables and observing the trend line. Figure 12 has a correlation coefficient of 0.600. This suggests that a correlation exists between the amount of training an operator has received and their level of stability knowledge.

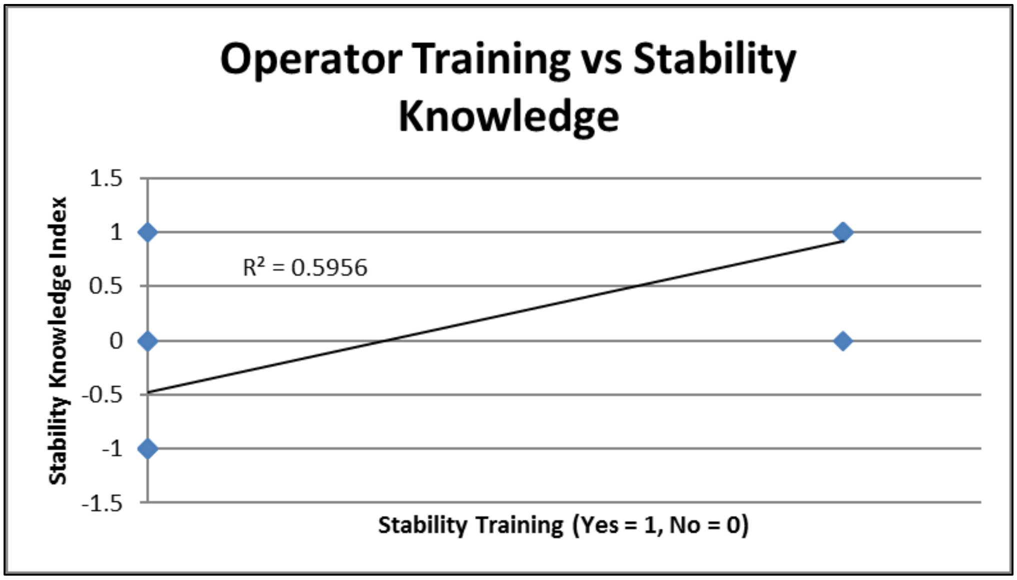

Figure 12: Operator Training vs Stability Knowledge

6.4.4 Distance from St. John's vs Stability Knowledge

Participants' locations were plotted against indices. Each participants' location was measured as the distance they lived from St. John's. The Marine Institute, which offers courses for Fishing Master certification, is located in St. John's. The analysis was conducted to determine if operators living closer to the Marine Institute are more likely to have better understanding of stability than those that those that live further away due to proximity or more availability of training. As per Figure 13, the correlation coefficient of 0.011 suggests a weak correlation between the two variables. The distance an operator lives from St. John's (and in effect, the Marine Institute) does not appear to have a significant impact on stability knowledge and risk awareness.

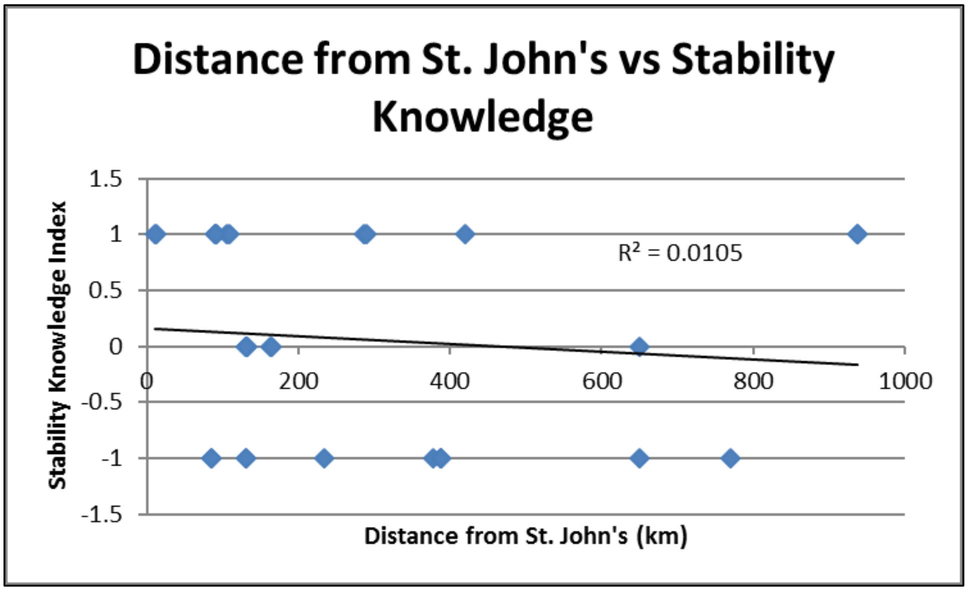

Figure 13: Distance from St. John's vs Stability Knowledge

6.4.5 Summary of Trends

The two variables with the most significant impact on operator stability knowledge were vessel length and training. These variables are not independent, as requirements for training are based largely on the size of a vessel. Experience or the distance an individual lived from St. John's did not appear to have a significant impact.

6.5 Near Miss Investigation

Near misses were investigated to supplement data on common causes of fishing vessel capsizes. As per Table 13, the most prevalent common cause identified from near misses obtained during interviews and roundtables was operators' practice. This cause played a significant role in 11 of the 13 near misses documented. This figure aligns with the causes identified from analysis of investigation reports, as operators' practice contributed to 57 of the 60 investigation reports studied.

Thirteen near misses were documented from discussions with 31[4] fishing vessel operators. The frequency of near miss events suggests that they are common among operators. However, the data collection methods of interviews and roundtable were not effective means of generating a large number of near miss events to supplement investigation reports. As per work by Wright and van der Schaaf (2004) and Jones at al (1999), there is a proportional number of near misses to reported accidents. While the exact ratio is disputed, it is agreed that there is a significantly higher number of near misses than reported accidents. As there were only 31 discussions with operators compared to 60 investigation reports analyzed, it was unlikely there would have been more near misses collected than accident reports.

While interviews and roundtables proved to be an effective means to assess operator's understanding of stability and provided 13 near misses, there are likely more effective ways to gather near miss information. This will be explored further in section 7.2.

6.5.1 Annual Probability of a Near Miss Incident

The number of near misses collected during this study (13) was divided by the total years of experience of all operators who participated in roundtables and interviews (1001). This provided the *annual probability of a near miss* (APN)*:*

$$APN = \frac{Number\ of\ Near\ Misses}{Total\ Years\ of\ Experience\ of\ Operators}$$

This calculation provided an annual probability of a near miss of 0.013 near misses/operator years. As per Table 21, there were over 44,000 operators employed in

[4] One operator participated in both the interview sessions and roundtable discussions (Interview Participant 7)

Canada in 2017. Multiplying this umber by the APN obtained in this study provides an estimate of 575.9 capsizing near miss events occurring in Canada in 2017. The number of capsizes in 2017 was 10. This provided a ratio of accidents to near misses of approximately 1:58. This proportion of accidents to near misses aligns with research by Jones et al. (1999) that discusses the dependant relationship between the two variables.

6.6 Primary Causes of Capsizing

The primary causes of fishing vessel capsizing events were divided into four main categories. These were identified from analysis of investigation reports in section 5.1 (see that section for a more detailed description of each of the primary causes). The decisions of operators played a role in all of the primary causes of capsizing incidents. This included direct operational decisions as the most common cause, covered by unsafe loading, operating with a free surface or with watertight integrity of the vessel knowingly compromised, and operating in harsh weather. These causes were identified in the published reports and also figured significantly in the reported near miss cases.

The other common causes of capsizing incidents were indirect operator decisions covered by unsafe modifications, lack of maintenance and minor design changes. These covered items such as owner installed equipment that significantly increased the center of gravity or alterations to the vessel's displacement and/or freeboard. In many cases, owners had an initial stability book approved for the vessel by their respective government's transportation officials. Following approval, owners would proceed to modify their vessel without accounting for the effect that the changes had on stability. Poor maintenance encompassed compromised watertight integrity and non-operational bilge pumps and alarm systems. The most significant example of hazardous minor design changes concerned freeing ports. In many cases, the areas of the freeing ports were insufficient, flaps were missing, or the flaps were welded shut, all rendering the freeing ports ineffective.

In this way, issues or decisions that were in the control of the owner/operator covered the vast majority of capsizing cases. The nature of fishing and the operation of fishing vessels provides an operator with a great deal of discretion in terms of the operations of, or modifications to, the vessel. Consequently, the safety of the vessel is, for the most part, in the hands of the operator. Thus, it is important that the operators and crew understand the stability related consequences of their decisions as the first line of defence against capsizing.

6.6.1 Example of Operator's Practice

The capsizing of the *Hope Bay* is an example of poor practice contributing to the capsizing of a vessel (Transportation Safety Board of Canada, 2004). The *Hope Bay* was a commercial fishing trawler with a length and gross tonnage of 72.6 feet and 126T, respectively. On February 26, 2004, the *Hope Bay* capsized and all four crew members died. The vessel was a small fishing vessel and was not required by Transport Canada to have any stability analysis. The owners, however, had a stability report approved in 1982 that stated that the maximum amount of ballast in the water tank be 5T. Beyond this amount, the TSB investigation report states, the vessel would have insufficient freeboard.

Post-accident analysis determined that the vessel most likely exceeded the 5T limit as described in the stability book. This led to a reduced freeboard which resulted in shipped water from wind and waves. In three to four metre waves, the vessel eventually flooded and capsized.

The Hope Bay is an example of stability books not being a useful tool to prevent capsizing because they are not well understood by operators. The operators did not follow the prescriptions of the stability analysis, probably as a result of a lack of understanding of vessel stability and/or the effect of raising or lowering the center of gravity or the impact of a free surface on the vessel's motions. Without this understanding, operators are more likely to make poor decisions despite having a stability book.

6.6.2 Example of Unsafe Modifications

An example of unsafe modifications is the capsizing of the *Caledonian* off the coast of Nookta Sound, BC on September 5, 2015 (Transportation Safety Board of Canada, 2016). The vessel capsizing led to the deaths of three of the four crew members. The *Caledonian* was built in 1975 with a length and gross tonnage of 30.63m and 259.92T, respectively. The vessel was therefore required to meet stability regulations outlined in the Large Fishing Vessel Inspection Regulations (LFVIR). The regulations were met in 1976 and the stability book was approved by Transport Canada.

Over the years, however, the lightship weight of the vessel significantly increased. In 1976, the stability assessment was performed with the lightship weight of 276T. By 2015, it was estimated that the weight had increased approximately 18% to 327T. The increase was gradual over the lifetime of the vessel and was attributed to, among other things, the addition of a net drum and trawl, empty space being used to store excess equipment, and water absorption in the fish holds. The increase in the vessel weight resulted in an increase in the height of the vessel's center of gravity and a reduction in the freeboard.

An updated light ship weight estimation of the *Caledonian* was not performed until the post-accident stability analysis following the capsizing in 2015. Analysis with the updated lightship weight concluded that the vessel no longer met the LFVIR regulations and the previous stability analysis was no longer valid. However, modifications to the vessel were never monitored and operations continued while the vessel's stability was continually reduced throughout its life. This series of effectively unsafe modifications that increased the vessel displacement was a contributing factor to the capsizing of the Caledonian. The fact that modifications were made over the lifetime of the vessel with no additional stability work suggests that the owner and/or crew were unaware of the effect that the modifications had on the stability of the vessel.

6.6.3 Example of Lack of Maintenance

Maintaining the seaworthiness of a vessel is the responsibility of the owner. An example of a lack of vessel maintenance is the *Lannie and Sisters II* (Transportation Safety Board of Canada, 2008). The *Lannie and Sisters II* was a small fishing vessel with a length and gross tonnage of 31.6 feet and 14.7T, respectively. On September 17, 2006, the vessel capsized "in good weather conditions," resulting in the deaths of two crew members. At the time of the accident, there was an ingress of water through the propeller shaft seal. The vessel had gone into dry dock to repair the leak but the problem persisted following repairs. The leak was made worse by vibrations due to damaged propellers. According to the TSB report, the owner and crew were aware of the problem but decided to continue operations. Furthermore, of the six pumps on the vessel, only one was operational. The TSB also questioned the integrity of the single operating pump because the wiring was of household grade held together with electrical tape as opposed to a marine grade connection. Because the vessel had a gross tonnage of less than 15T, it was not required to undergo any inspections by Transport Canada.

The leak in the stuffing box resulted in the vessel taking on water. Because of the reduced pump capacity, the crew were not able to rid the vessel of the water. The water reduced the vessel's stability by introducing a free surface effect and reduced freeboard. The vessel also had an inherent 5° list to starboard that would have increased as the water was taken on. The TSB report concludes that this was the most likely cause of the vessel sinking/capsizing in good weather. The fact that the vessel was operated with such poor upkeep suggests that the operators did not understand the effect that shipped water had on the vessel's stability. The risk that was taken by operating the vessel in such poor shape could have been avoided with a better understanding of stability.

6.6.4 Example of Small Scale Design

An example of poor design contributing to the capsizing of a vessel is the capsizing of the *Lannie & Sisters II* as discussed in the previous section (Transportation Safety Board of Canada, 2008). Upon recovery of the vessel it was discovered that the freeing ports had no flaps to prevent the ingress of water through freeing ports that had been cut into the hull. This would have led to an increase of the ingress of water.

6.6.5 Multiple Causes: Capsizing of the *Melina & Keith II*

Rarely can capsizing be attributed to a single cause. As per Table 8 and Table 9, in many cases, it is often a combination of causes that leads to a vessel capsizing. This is illustrated by the *Melina & Keith II* capsizing incident. The *Melina & Keith II* was a small fishing vessel operating off the coast of Bonavista, NL, when it capsized on September 12, 2005. The *Melina and Keith II* had a length and gross tonnage of 61.6 feet and 126.6T, respectively. Prior to capsizing, the crew were hauling nets through doors on the starboard side of the vessel. The TSB report notes that during hauling operations, the vessel had a starboard list. When approximately half of the nets were on board, there was a “moderate roll to starboard” that resulted in about 5cm of shipped water. The pumps were able to handle the initial shipped water and the vessel recovered. A short time later, another starboard roll occurred and the vessel took on 15-20cm of water, which the pumps could not handle. With a heavy list, the vessel rolled once more and water entered the vessel “steadily” through the hauling door. As the crew rushed to the port side of the vessel, the *Melina & Keith II* capsized. Four of the eight crew members on board at the time of the accident died (Transportation Safety Board of Canada, 2007).

As per TSB’s investigation report, multiple causes played a role in the capsizing of the *Melina and Keith II*. An important contributing factor was operator’s poor practice in loading the vessel. First of all, the vessel had an inherent starboard list that was most likely due to asymmetrical placement of fixed weights on the vessel. This list was worsened further by loading fish, shrimp, and ice in the port and starboard pens. The TSB reported that the weight of the contents in the starboard side pen was approximately 3T greater than that of the port side pen. The effect of the list on the vessel was detrimental to stability because it reduced the vessel’s righting moment and freeboard on the starboard side. Furthermore, the vessel was considered heavily loaded at the time of the capsizing. This reduced the vessel’s freeboard and made it more susceptible to shipped water. In the case of the *Melina and Keith II*, the operator's poor practice is twofold: first, operating with an inherent starboard list makes the vessel more vulnerable to capsize for the reasons mentioned previously. Second, the original list was worsened by unsafe loading. These poor practices suggest that the operator lacked an adequate knowledge of stability and the detrimental effects that improper loading can have on a vessel.

While the operator's actions undoubtedly played a large role in the capsizing of the *Melina and Keith II*, unsafe modifications were also reported to have reduced the vessel's initial stability and put it at a greater risk of capsizing. In 2000, the TSB reports, the vessel underwent major modifications that increased the displacement and the vertical center of gravity of the vessel. Not only did this reduce the vessel's freeboard, but the increase in the center of gravity reduced the transverse stability. Finally, the freeing ports of the vessel were welded shut during these modifications. This would prove hazardous as it prevented any shipped water from clearing from the deck and the free surface effect from the shipped water further reduced the vessel's transverse stability.

As there was no stability assessment performed following the modifications in 2000, it can be concluded that the modifications were made without consideration of the potential impact on the vessel's stability. The decision to not perform stability work following modifications that substantially increased the vessel's displacement is indicative that the owner lacked knowledge of the significance of the changes on the vessel stability. The design decision to weld freeing ports shut also suggests that owner did not consider, or was not aware of, the free surface effect of the shipped water that could be not be cleared without freeing ports.

The TSB's report also discussed the fact that as a small fishing vessel, the *Melina & Keith II* was not required to submit stability data and still met the regulations of the SFVIR. As discussed by the TSB, the *Melina & Keith II*, like many other SFVs, was at a greater risk of capsize than vessels meeting other class requirements (such as the Large Fishing Vessel Inspection Regulations) because of the lax regulations. The vessel's likelihood of capsize was increased due to unsafe modifications and operator's poor practice, both reflecting a lack of understanding of vessel stability and awareness of the risk posed by capsizing.

6.7 Operators' Understanding of Stability

Operators' understanding of stability plays a critical role in a fishing vessel's safe operation. The results of the analysis of investigation reports, roundtables, and interviews all provided information that allowed for a general assessment of operators' understanding of stability.

6.7.1 Investigation Reports

The four most common contributors to vessel capsizes were identified as operators' practice, unsafe modifications, lack of maintenance, and small scale design flaws. All of these causes can be, at least, partially attributed to a lack of understanding of vessel stability and awareness of the risk of capsizing.

Operators' practice contributed to an overwhelming majority of capsizing events. At 95%, operators' practice presents itself as the most significant contributor to a vessel capsizing. The decisions operators make while fishing that impact their vessel's stability are likely a reflection of their understanding of vessel stability. The fact that poor loading (and other operators' decisions) were as prevalent as they were in the analysis suggests a lack of understanding of basic stability principles by operators involved in the accidents.

As capsizing events continue to occur, it is clear that, in the majority of cases, causes are a direct result of, or can be linked to, operators not understanding stability. Owners and crews unknowingly put themselves in danger. To reduce capsizing incidence, it would be most effective to educate owners and operators on stability concepts and effects as related to the design and operation of their vessel. Operators should be equipped with sufficient knowledge of stability to make informed decisions that will improve safety in the commercial fishing industry.

6.7.2 Interviews and Roundtables – Benefits of Training

The interviews demonstrated that operators who have received formal stability training have a strong understanding of vessel stability. The ability to identify when stability is initially poor or has been reduced during operations is necessary to take preventive measures to avoid capsizing.

Operators with formal stability training also tended to be familiar with technical concepts such as metacentric height and the free surface effect. They were able to relate these concepts to the stability of their vessel and this was reflected in best practices the group discussed. Some of the operators were able to use a stability book but rarely did they consider it an important tool to ensure that stability was maintained. No operator interviewed with stability training felt that stability documentation alone was sufficient to ensure a stable vessel. There was consensus among the group that operators' decisions play the most important role in regards to stability.

There was a significant discrepancy in the level of knowledge of operators who received stability training and those who did not. Operators without formal stability training did not demonstrate a strong understanding of stability. This was most obvious when no operator in the interview group understood the relationship between comfort and stability of a vessel. This suggests that untrained operators may not be aware of a situation developing in which their vessel is becoming susceptible to capsizing.

Some operators, most often with 30 or more years of experience but without stability training, mentioned multiple actions they performed to maintain stability that were examples of good practice. While they did not understand the technical details, this group was generally aware of common hazards that can reduce stability. This indicates that in some cases, long experience and intuition has led to good practice.

Operators without stability training were generally less concerned with capsizing than those with stability training. Untrained operators were also more likely to blame vessel design as opposed to operator practice as the primary cause of many capsizing events. This again returns to the conclusion that operators without stability training are less aware of the risk posed by capsizing. Specifically, they are more likely to assume their vessel is stable with less regard to how their actions impact stability.

Results from roundtables suggested that the level of operators' understanding of stability depends largely on the amount of formal training an operator has received. There was an evident discrepancy in the level of knowledge of operators who had received formal stability training and those that did not. Further, those with formal training showed a greater awareness of the risk of capsizing. The gap in knowledge between the two groups of operators was apparent throughout the roundtables.

The impact that formal stability training had on operators' understanding of stability was apparent from the interviews and roundtable discussions. From interviews with operators, there was a clear divide between operators who had received formal stability training and those that had not. Operators with no training did not have as strong an understanding of stability and were less concerned with the risk of capsizing. However, untrained interview participants appeared as capable operators. Even without training, these interview participants were aware of best practices. This alludes to the importance of experience concerning safe operation of a fishing vessel.

From discussions with operators during both the interviews and roundtables, there was an observable relationship between an operator's understanding of vessel stability and the amount of stability training received. In general, there was a positive correlation between these two variables. Operators who had received some form of technical training showing a greater understanding of stability and awareness to the risk of capsizing than those who did not.

6.7.3 Discrepancy in Roundtables and Interviews

Regarding operators without stability training, there was some discrepancy in the level of stability knowledge of interview participants and roundtable participants. Interview participants' knowledge was much more consistent amongst the group, while there was a wider spectrum for roundtable participants. There are two factors that have been identified as the most probable causes of the discrepancy.

First, the influence of other members of roundtable sessions must be considered when taking participants' answers into account. There is a chance that a participant may answer a question based on a previous participant's answer and the group's reception to that answer. Because of this possibility, interviews are considered a more reliable way to assess operators' understanding of stability.

The second factor is the range of experience of roundtable participants was greater than that of interview participants. This provided a correspondingly wide range of responses. This illustrates the importance that experience has for operators with no stability training. While experience is not a replacement for education, it provides operators with valuable intuition that can be used to make informed decisions.

6.8 The Link between Investigation Reports and Discussions with Operators

Before any recommendations can be made to reduce the frequency of capsizing in NL, it is important to establish a link between the results from the analysis of investigation reports (section 5.1) and from discussions with operators (sections 5.3 and 5.4). The primary conclusion from the analysis of common causes of fishing vessel capsizes is that the decisions and actions of operators have by far the most significant impact on the likelihood of a vessel capsizing. This finding is most strongly supported by the statistic that operators' actions played a role in 95% of the capsizes studied. Operators' actions and decisions was the most common primary cause found in the analysis by approximately 60%.

Any operator's action or decision that increases or reduces the probability of a vessel capsizing is likely a reflection of that operator's understanding of stability. This is especially relevant for a capsizing event that is deemed to have occurred due to, at least in part, how an operator loaded their vessel. Overloading or added top weight contributed to 40 of the 60 capsizes studied in section 5.1. It is difficult to attribute these actions to anything but a lack of understanding of vessel stability.

Discussions with operators during both the roundtables and interviews suggested a strong correlation between an operators' understanding of stability and risk awareness and the amount of training the operator had received. Therefore, it is probable that an increase in training among members of the NL fishing community would result in an overall improved understanding of stability. With an improved understanding of stability, the number of operators' decisions that make a vessel more susceptible to capsizing may be reduced. Better informed operators will likely reduce the frequency of capsizing in NL.

The premise that training is the best defense against capsizing is supported by statistics analyzed of capsizing events in Canada from 2004 to 2017 (see section 6.2). As described in that section, the trend of capsizes per employment suggests that these events are declining over that same time frame. A possible explanation for this trend is the fact that as of 2007, operators receiving a Fourth Class ticket have been required to undergo formal stability training. In order to make a more definitive conclusion, additional analysis that accounts for the number of operators who have formal stability training may provide stronger evidence but the conclusions from the current study point strongly in the direction of operator training. An increase in the proportion of operators who receive stability training should be the most effective means to further reduce capsizes in the future.

7.0 Recommendations

Based on the findings from investigation reports and discussions with operators, the most significant root cause of fishing vessel capsizing events is a lack of stability awareness on the part of operators. This covers operational actions, vessel modifications and issues of maintenance. Operator's stability awareness, or lack thereof, can be directly linked to the amount of formal training received although some fishers with long experience have gained similar knowledge and awareness. As the number of operators who receive some form of stability training increase, it is likely that the number of stability related incidents involving fishing vessels will decrease. Therefore, in order to reduce capsizes of fishing vessels in Newfoundland and Labrador, an educational program leading to improved awareness knowledge of stability among members of the fishing community is strongly recommended.

Many vessels in Canada do not require operators with any formal stability training (DFO, 2016). Conclusions can be made with reasonable confidence that a significant percentage of operators in Canada lack any stability education. Included in this group are any operators who received a Fishing Master Fourth Class certificate or less prior to 2007. After 2007, training became more extensive with the introduction of the "Ship Stability and Construction 1" (SCS-1) course to the Fishing Master Fourth Class certification program. As of 2018, certification for vessels not requiring a Fourth Class certificate still does not include formal stability training. Refer to section 3.2 for more detail. As demonstrated from discussions with operators, operators who have not completed some form of stability training are less likely to have an adequate understanding of vessel stability.

7.1 The Need for Improved Understanding of Stability

In order to improve both awareness of the risk of capsizing and understanding of general stability principles in Newfoundland and Labrador, it is recommended that an educational program be put in place for operators who currently have not received formal stability training. The program's main objective would be to better educate operators on stability principles and practice with the ultimate aim of avoiding capsizing events. During interviews and roundtables, all participants expressed openness (of varying degrees) to an educational program with the potential to improve operations. Based on these discussions, it is recommended that such a program be offered through an organization such as the NLFHSA. Furthermore, groups are more likely to be receptive to any training program that is instructed by a fellow operator. This is based on discussions in which participants expressed a lack of regard for those without any fishing experience making regulatory decisions.   This view may extend to an instructor.

The primary deliverables for an educational stability program would be based on what is currently being taught in the SCS-1 course that is part of the Fishing Master Fourth Class certificate. Operators who are confident and knowledgeable in the components offered by this course are much more likely to make decisions while fishing that reduce the likelihood of a capsizing event. An outline of the proposed stability program is discussed in section 8.0 and Table 24. Subject titles are taken directly from Transport Canada's *The Examination and Certification of Seafarers 6th Revision* section detailing the SCS-1 course of the Fishing Master Fourth Class certificate (p. 261). Extensive details on each subject can be found in that document.

7.2 Other Recommendations

This research has identified a possible explanation for the trend in decreasing capsizing events in Canada and suggests that this trend may be due to improved training among fishing vessel operators (see section 6.2.2). This assessment was made while considering the number of fatalities reported by TSB and employment numbers in the fishing industry. At the same time, fishing vessel operator training requirements were considered. While this information allowed for a speculative conclusion to be drawn, it is possible to form a more definite and confident conclusion if more information was made available. In particular, there was no information available that detailed the number of operators each year who had received some form of formal stability training in Canada. This information could be applied to the number of capsizing fatalities per employment to make a more confident assessment of the role that formal training has on the frequency of capsizing. It is recommended that governing bodies such as TC keep track of this statistic to be used for future research.

Documenting near miss capsizing events was an original goal of the project. These could be used to supplement investigation reports to identify the most frequent causes of capsizing. As discussed in section 2.4, documenting near misses has been used in other industries to successfully reduce accidents. In order to supplement investigation reports with near misses, the number of near misses should be much higher than the number of reported accidents. Recruitment of operators via interviews and roundtables was not an effective way to collect near misses.

Currently, there is no such near miss reporting system in the Newfoundland and Labrador fishery. The introduction and implementation of a system could help to reduce not only capsizes in the province, but all types of incidents related to fishing vessels. It has been shown in other industries that near miss reporting tends to increase the overall safety culture of an operation. An anonymous online reporting system is a potential way to document near misses. Operators could use the system to report any near miss events. They would describe the incident to the best of their ability. From this description, an investigator would make an attempt to attribute a possible cause to the event. If such a system is to be implemented successfully, operators must be encouraged to report near miss incidents without fear of reprisals from their employers or government officials.

Possible future work would be the development of a near miss reporting system. If this system can record a large number of near misses (compared to accident reports), it will be possible to determine common causes of capsizes, and other accidents, with greater confidence. A possible impediment to this system may be a lack of incentive for operators to report near misses. This aspect should also be included in any future study.

8.0 Outline of Proposed Stability Educational Program

The primary recommendation from this research to reduce capsizing in Newfoundland and Labrador is the introduction of a stability education program in the province. In order to receive certification from the Professional Fish Harvesters Certification Board (PFHCB), operators who have not completed some form of formal stability training would be required to complete the program. The program is made up of two sections: maintaining vessel stability and maintaining seaworthiness of a vessel. The subjects in each section address all of the causes highlighted in the analysis of capsizing investigation reports (section 5.1). Within each section, the program is designed to be followed sequentially as presented in Table 24. The program begins by emphasizing basic stability principles. Once participants have a strong grasp on this aspect, they would move towards applying that knowledge to vessel operations. The program totals 40 hours, designed to be separated into five eight-hour days.

Outline for Stability Educational Program			
Maintain Vessel Stability		Maintain Seaworthiness of the Vessel	
Subject	Estimated Duration (Hours)	Subject	Estimated Duration (Hours)
Understanding Stability Basic Terminology	4	Fishing Vessel Types	1
Understanding Transverse Stability Principles	6	Maintain Integrity of the Hull and Superstructures and Prevent Water Flooding	6
Effect of Vessel's Operations Including Catch Handling	4	Survivability of the Vessel in Case of Flooding and Damage Control	4
Effect of Environmental Conditions on Vessel's Stability	4	Vessel Inspection and Maintenance	5
Effect of Vessels and Gear Modifications on Vessel's Stability	4		
Estimating the Metacentric Height of a Vessel and the Height of the Vessels COG	2		
Total	24	Total	16
Total Duration of Program: 40 Hours			

Table 24: Outline for Proposed Stability Educational Program

It is important that any proposed stability education program address the common causes that have been highlighted in section 5.1. Table 25 highlights which module addresses these common causes. As is shown in the table, a program covering what is currently taught in SCS-1 would effectively address the common causes identified as the primary contributors to many fishing vessel capsizes.

		Operator's Practice						Poor Design		
		Unsafe Loading	Operating with F.S.	Operating with watertight integrity (knowingly) compromised	Operating in harsh weather	Unsafe Modifications that Reduced Stability	Lack of Maintenance that led to an Ingress of Water	Freeing ports insufficient	Bilge pumps and/or alarm system insufficient	Equipment installed in location that increased COG
Maintain Vessel Stability	Understanding Stability Basic Terminology									
	Understanding Transverse Stability Principles	✓								✓
	Effect of Vessel's Operations Including Catch Handling	✓								
	Effect of Environmental Conditions on Vessel's Stability				✓					
	Effect of Vessels and Gear Modifications on Vessel's Stability					✓				
	Estimating the Metacentric Height of a Vessel and the Height of the Vessels COG	✓								
Maintain Seaworthiness of the Vessel	Fishing Vessel Types									
	Maintain Integrity of the Hull and Superstructures and Prevent Water Flooding			✓			✓			
	Survivability of the Vessel in Case of Flooding and Damage Control		✓					✓	✓	
	Vessel Inspection and Maintenance						✓			

Table 25: Common Causes Addressed by Proposed Stability Education Program

Further to the concepts outlined in the table, the following recommendations are made to enhance the likelihood of an educational program being successful in reducing the frequency of capsizing events in Newfoundland and Labrador:

- The course is to be offered through the NLFHSA (or other approved training providers). In order for operators to be licenced through the PFHCB, operators would have to complete this program if they do not currently hold certificates that include formal stability training.
- The course is to be instructed by a fishing vessel operator with an extensive knowledge of vessel stability. As minimum requirement, the instructor is to

have completed the SCS-2 (a more comprehensive version of SCS-1) course and have extensive operating experience.

- The course should make significant use of demonstrations to illustrate technical concepts. Note taking should be kept to a minimum. The course should include hands on opportunities for participants.
- The subject “Understanding Transverse Stability Principles” should have sufficient time allotted to discussing the relationship between vessel stability and vessel motions. This relationship can seem counterintuitive and is often misunderstood by operators if they have not received formal stability training. It is dangerous if operators do not understand this basic stability principle because they are likely to believe that a “comfortable” vessel implies stability.
- When covering the free surface effect, the program should discuss in detail the detrimental effects of certain types of species that can behave as a liquid. In particular, pelagic species were often discussed in the roundtables and interviews as posing a significant risk of a shifting load. The dangers of sea cucumbers should also be discussed. Sea cucumbers were often brought up in discussions with operators as being the most dangerous species to fish for.
- The program modules are to each incorporate case studies of capsizing events using Transportation Safety Board investigation reports. Discussions on the causes of each event will highlight the consequences of a lack of stability knowledge.
- The course should emphasize the risk of capsizing to create improved awareness among participants.

- Participants must receive a passing grade on a written assessment at the end of the week.
- The course could also introduce the idea of near miss reporting as a means of improving safety culture and the operations of specific vessels.
- Following completion of the program, a handbook outlining best practices should be given to participants to be used as a reference

Programs of similar nature have been implemented in BC (Fish Safe's four-day long *Stability Education Course)* and in the UK (Seafish offers three one-day stability awareness courses of varying complexity). These courses address the primary causes of vessel capsizes that have been outlined in this study. In particular, they stress the impact that loading has on a vessel's stability and the importance of maintaining watertight integrity. The courses are also instructed by fellow harvesters which is an important consideration for a similar program in NL. These programs have been implemented successfully and there is no reason to believe a similar program could not be utilized in the province to improve education and awareness of stability related issues among operators. Equipped with a stronger understanding of vessel stability, operators in the province are more likely to make better decisions that reduce the likelihood of capsizing their vessel.

9.0 Conclusion

As in many of the world's developed countries, capsizing of fishing vessels continues to pose a problem in Canada. In Newfoundland and Labrador in particular, the tight knit fishing community has been hit hard by fatalities from stability related incidents such as the *Ryan's Commander*, *Melina & Keith II*, and the *Pop's Pride*. As capsizing has one of the highest fatality rates among fishing vessel accidents, reducing the frequency of these events would likely result in a noteworthy reduction in the number of fatalities in the province's fishing industry. This thesis attempts to take a methodical approach to establish a link between the common causes of fishing vessel capsizing and operators' understanding of stability. From the link between these two parameters, the thesis proposes recommendations for a stability awareness program to reduce the frequency of fishing vessel stability incidents in NL.

Based on findings from the research, it is recommended that in order to reduce fishing vessel capsizing events in NL, stability awareness be improved among operators. This could be done through an education program that would be offered through an organization such as the NLFHSA. Similar programs have been implemented in other parts of Canada and in other countries and there is no reason to believe a stability education program could not be successful in NL. The program should be aimed towards operators who are currently not required to undergo formal stability training by Transport Canada. In order to be certified as a professional fish harvester in Newfoundland and Labrador, it is recommended that these operators complete a program similar to one that has been outlined in section 8.0.

While the risk of capsizing will never be completely eliminated in the fishing industry, it can be reduced through improved education and awareness. To reiterate what was brought up in a roundtable session by an operator: "Education awareness allows you to take a *calculated risk* as opposed to a *blind risk*."

10.0 References

Applied Research and Evaluation Services. (2008). Fish Safe Stability Education Course Evaluation Survey.

Department of Fisheries and Oceans Canada. (2016, October 06). Commercial fisheries and aquaculture. Retrieved from http://www.dfo-mpo.gc.ca/stats/commercial/cfs/2008/section3-eng.htm

Department of Fisheries and Oceans Canada (2011, February 1). Vessel replacement rules and procedures on the Atlantic Coast - discussion paper. Retrieved from http://www.dfo-mpo.gc.ca/fm-gp/policies-politiques/vessel-bateau/index-eng.htm

Department of Fisheries and Oceans Canada (1996, July 1). Chapter five - Policies for vessels 19.8m (65') LOA and greater. Retrieved from http://www.dfo-mpo.gc.ca/reports-rapports/regs/licences-permis/ch5-eng.htm

Employment in fishing industry. (2017, January 9). In Newfoundland & Labrador Statistics Agency. Retrieved from http://www.stats.gov.nl.ca/statistics/Labour/PDF/Employment_Fishing_Industry.pdf

Fish Safe. (2018). Stability Education Course. Retrieved from http://www.fishsafebc.com/stability-course/

Gonzalez, M.M., Casas, V.D., & Caamano, L.S. (2016). Real-time stability assessment in mid-sized fishing vessels. In A. Rosen & M. Schreuder (Eds.) Proceedings of the 15th International Ship Stability Workshop. (pp.1-8). Stockholm, Sweden. Chalmers University of Technology and KTH Royal Institute of Technology.

González, M. M., Sobrino, P. C., Álvarez, R. T., Casás, V. D., López, A. L., & Peña, F. (2012). Fishing vessel stability assessment system. Ocean Engineering, 41, 67-78.

Gourlay, T.P. & Lilienthal, T. (2002). Dynamic stability of ships in waves Proceedings of Pacific 2002 International Maritime Conference at Pacific 2002 International Maritime Exposition. (pp. 1-9). Sydney, Australia. Sydney Convention and Exhibition Institution of Engineers, Barton, ACT

Government of Canada. (2017, February 3). Large fishing vessel inspection regulations. Retrieved from http://laws-lois.justice.gc.ca/eng/regulations/C.R.C.%2C_c._1435/FullText.html.

Howe, B., & Johansen, G. (2007). The fishing vessel stability education program: an informed blueprint for program design. Proceedings of 2007 Annual Conference and Exposition. (pp. 1-9). Honolulu, Hawaii. American Society of Engineering Education.

Heinrich, H. (1950). Industrial accident prevention; a scientific approach. (3d ed.). New York: McGraw-Hill.

International Maritime Organization. (2018). Fishing vessel safety. Retrieved from http://www.imo.org/en/OurWork/Safety/Regulations/FishingVessels/Pages/Default.aspx

International Maritime Organization. (2012). Cape Town Agreement on safety of fishing vessels adopted in South Africa. Retrieved from http://www.imo.org/en/MediaCentre/PressBriefings/Pages/44-SFV-conf-ends.aspx#.XDjYNM5KhhE

Johnson, B. & Womack, J. (2001). On developing a rational and user-friendly approach to fishing vessel stability and operational guidance. In A. Francescutto (Ed.) Proceedings of 5th International Workshop Stability and Operational Safety of Ships. (pp. 53-62). Trieste, Italy. University of Trieste.

Johnson, B. & Grochowalski, S. (2002). Development of a performance based on fishing vessel stability criteria; a methodology based on scalable model tests. In S. Grochowalsi (Ed.) Proceedings of 6th International Ship Stability Workshop. (pp. 1-9). New York, New York. STAB International Standing Committee.

Jones, S., Kirchsteiger, C., & Bjerke, W. (1999). The importance of near miss reporting to further improve safety performance. Journal of Loss Prevention in the Process Industries, 12, 59-67.

Kaplan, I.M. & Kite-Powell, H.L. (2000). Safety at sea and fisheries management: fishermen’s attitude and the need for co-management. Marine Policy, 24, 493-497.

Lloyd’s Register Foundation. (2018). Insight Report on Safety in the Fishing Industry. London, England: Author.

Loughran, C.G., Pillay, A., Wang, J., Wall, A., & Ruxton, T. (2002). A preliminary study of fishing vessel safety. Journal of Risk Research, 5(1), 3-21.

Lucas, Kincl, Bovbjerg, Branscum, & Lincoln. (2014). Primary prevention of fishing vessel disasters: Evaluation of a United States Coast Guard policy intervention. Marine Policy, 50(PA), 67-73.

Lynda Griffiths and Associates, (2009). Focus Group with Fishermen: Fish Safe Stability Education Program. A Summary of Findings.

Melina and Keith II sinking report urges reform. (2007, October 4). Retrieved from https://www.cbc.ca/news/canada/newfoundland-labrador/melina-and-keith-ii-sinking-report-urges-reform-1.637013

Molyneux, D. (2007). The safety of small boats (including fishing boats) against capsize: a review. Retrieved from https://nparc.nrc-cnrc.gc.ca/eng/view/fulltext/?id=8a2538e7-2179-44ad-84f8-c415514cbdcf

Munro-Smith, R. (1967). Applied naval architecture. New York: American Elsevier.

Nielsen, K.J., Cartensen, O., & Rasmussen, K. (2006). The prevention of occupational injuries in two industrial plants using an incident reporting scheme. Journal of Safety Research, 37, 479-486.

Pérez Rojas, L., Abad, R., Pérez Arribas, F., & Arias, C. (2007). Some experimental results on the stability of fishing vessels. Proceedings of the 8th International Conference on the Stability of Ships and Ocean Vehicles. (pp. 643-653). Hamburg, Germany. Germanischer Lloyd.

Richer, S. (2007, October 12). *Fishing village grieves in rain for lost sons.* Retrieved from https://www.theglobeandmail.com/news/national/fishing-village-grieves-in-rain-for-lost-sons/article1141594/

Roberts, E.S. (2002). Hazardous occupations in Great Britain. The Lancet, 260(9332), 543-544.

Seafish (2014). ½ Day basic stability awareness course specification 2014.

Seafish (2014). 1 Day basic stability awareness course specification 2014.

Taguchi, H., Matsuda, A., & Shoji, K. (2013). Experimental investigation into accidents of two Japanese fishing vessels. Proceedings of the 13th International Ship Stability Workshop. (pp.1-8). Breast, France. STAB International Standing Committee.

Transport Canada. (2014, January 7). Vessel Stability. Retrieved from https://www.tc.gc.ca/eng/marinesafety/debs-vessel-stability-menu-1193.htm#3

Transport Canada. (2017, February 8). Coming into force of Phase 1 of the New Fishing Vessel Safety Regulations - SSB No.: 03/2017. Retrieved from https://www.tc.gc.ca/eng/marinesafety/bulletins-2017-03-eng.htm

Transport Canada. (2013, August 7). Subject: Fishing Vessel Safety: Record of Modifications. Retrieved from https://www.tc.gc.ca/eng/marinesafety/bulletins-2008-01-eng.htm

Transport Canada. Marine Safety Directorate. (2016). The examination and certification of seafarers (6th ed.) Ottawa, ON.: Marine Safety.

Transport Canada. Marine Safety Directorate. (2007). The examination and certification of seafarers (5th ed.) Ottawa, ON.: Marine Safety.

Transport Canada. Marine Safety Directorate. (2004). The examination and certification of seafarers (4th ed.) Ottawa, ON.: Marine Safety.

Transportation Safety Board of Canada. (2006). Capsizing and loss of life: Small fishing vessel "Ryan's Commander" 5 nautical miles East of Cape Bonavista, Newfoundland and Labrador, 19 September 2004. (Marine occurrence report; M04N0086). Ottawa]: Minister of Public Works and Government Services.

Transportion Safety Board of Canada. (2004). Capsizing and Loss of Life Small Fishing Vessel Hope Bay Queen Charlotte Sound, British Columbia 26 February 2004. (Marine Occurrence report: M04W0034). Ottawa, ON]: Minister of Public Works and Government Services.

Transportation Safety Board of Canada. (2016). Capsizing and loss of life Fishing vessel Caledonian 20 nm west of Nootka Sound, British Columbia 05 September 2015. (Marine Occurrence report: M15P0286). Ottawa, ON]: Minister of Public Works and Government Services.

Transportation Safety Board of Canada. (2008). Sinking with loss of life: Small fishing vessel Lannie & Sisters II, Notre Dame Bay, Newfoundland and Labrador, 17 September 2006. (Marine investigation report; M06N0074). Ottawa, Ont.]: Transportation Safety Board.

Transportation Safety Board of Canada. (2007). Capsizing and loss of life: Small fishing vessel Melina & Keith II, Bonavista, Newfoundland and Labrador, 70 nm E, 12 September 2005. (Marine Investigation report; M05N0072). Ottawa]: Transportation Safety Board of Canada.

Transportation Safety Board of Canada. (2016). Sinking and subsequent loss of life Small open fishing vessel Pop's Pride Cape Spear, Newfoundland and Labrador 06 September 2016. (Marine Investigation report; M16A0327). Ottawa]: Transportation Safety Board of Canada.

United States Coast Guard. (n.d.). In This page is for The Alternate Compliance and Safety Agreement (ACSA). Retrieved from http://www.fishsafewest.info/acsa.asp

Walpole, R., Myers, R., Ye, S., & Ye, Keying. (2012). Probability & statistics for engineers & scientists (Ninth ed.).

Wang, J., Pillay, A., Kwon, Y.S., Wall, A., & Loughran, C.G. (2005). An analysis of fishing vessel accidents. Accident Analysis and Prevention, 37, 1017-1024.

Wiseman, M., Burge, H., & National Search Rescue Program. National Search Rescue Secretariat. (2000). Fishing vessel safety review (less than 65 feet). St. John's, N.L.: Maritime Search and Rescue, Newfoundland Region.

Womack, J. (2002). Small commercial fishing vessel stability analysis: Where are we now? Where are we going? Marine Technology and SNAME News, 40(4), 296-302.

Wright, L. & van der Schaaf, T. (2004). Accident versus near miss causation: a critical review of the literature, an empirical test in the UK railway domain, and their implications of other sectors. Journal of Hazardous Materials, 111, 105-110.

Appendix A: Roundtable Outline

Capsize Prevention for Fishing Vessels: Focus Group Outline

Outline for Focus Group

Introduction

- Welcome participants and thank them for coming
- Pass out consent form and allow participants to read over them. Discuss and answer any questions they may have

Begin session

- Go around the table. Each participant begins with the following:
    - name
    - where they live/where they fish
    - how long they've been fishing
    - what type of vessel(s) they use
    - what type of fisheries/species are they involved in
- What does it mean to have a stable vessel?
    - How do you know/determine if your vessel is stable?
    - What things do you consider in determining the stability of your vessel?
    - Is your vessel equipped with a stability book? Do you think the stability books are useful?
    - What's more important: Initial/inherent vessel stability or operators' operations?
- How do you maintain the stability of your vessel?
    - What do you do to maintain the stability of your vessel?
    - Do you <u>always</u> do/consider these things? If not, why not?
    - Do you think most operators do/consider these things? If not, why not?
- What poses the largest risk to the stability of a vessel?
    - In your opinion and experience, what are the things that pose the largest/greatest risk to fishing vessel stability and capsizing?
    - In your opinion and experience, what are the most common things that pose a risk to fishing vessel stability and capsizing?
    - Introduce case study of capsizing? What's your opinion of the situation? Could it have been prevented? How?
        - Use TSB report
- Have there been instances when you have felt: 1) that the vessel's stability was compromised or 2) that your vessel was close to capsizing?

- What happened?
- In your opinion, why did it happen?
- How often?
- Is this common in the fishing industry?

- What would you consider the most effective way to reduce/prevent the loss of stability or capsizing?
    - Stability books/stability testing?
    - Formal stability training?
    - Encouraging (through education/awareness) stability best practices?
- Have you completed any type of training in vessel stability or stability best practices?
    - Would you be interested in a course/training on vessel stability? Why or why not?
    - What type of course do you think would be most effective?
    - Do you think other harvesters would be interested in such a program?
    - What do you think of BC's Safe Catch program? Could something similar be implemented in NL? Why or why not?

<u>Wrap up session</u>

- Thank everyone for their time
- Provide contact information
- Explain that I'm interested in individual interviews with anyone who has had a near miss. They can contact me privately if they'd be interested in participating

Appendix B-1: Capsizing Incident Report's Vessel Details

No	Canada										
	Vessel							Date	Weather		Stability
No	Vessel Name	Report Number	Gross Tonnage (Te)	Length (m)	Length (ft)	Beam (m)	Vessel Class	Date dd/mm/yyyy	Wind (knots)	Wave Height (m)	Stability Work Performed
1	Ryan's Commander	M04N0086	149.4	19.79	64.93	7.32	SFV	9/19/2004	35-48	3-4	- Not required to perform any stability work as per SFVIR - Optional abbreviated inclining experiment performed by NA. Not as thorough as tests required by TC. Result was Not accurate because incorrect displacement was used. - RC was compared to "Elite Voyager" which had stability work done and met TC regulations. But dimensions of vessels did not agree. - Post accident analysis showed various criteria below SFVIR stab 4 criteria, most notably the range of positive transverse stability
2	Lannie & Sisters II	M06N0074	14.7	9.63	31.59	NA	SFV	9/17/2006	5-15	N/A	- No stability work required or performed
3	Melina & Keith II	M05N0072	126.62	18.78	61.61	NA	SFV	9/12/2005	10-15	2	- No stability work required or performed
4	Big Sister	M07M0088	13.54	10.7	35.10	NA	SFV	11/13/2007	20-25	1-2	- No stability work required or performed
5	Cape Fin-Tose	M06N0082	98.5	19.79	64.93	NA	SFV	11/1/2006	5	Calm Seas	- Inclining experiment performed - Two stability books written and submitted for approval at the time of capsize: one for shrimp and crab; another for herring, capelin, or mackerel. Both booklets met TC regulations
6	L' Acadien II	M08M0010	34.36	12.56	41.21	NA	SFV	3/29/2008	10-15	N/A	
7	Strait's Pride II	M90N5017	93	19.83	65.06	6.64	SFV	12/17/1990	30-45	4-6	- No stability work required or performed
8	Miss Cat Harbour	M97N0093	11.9	14.9	48.88	NA	SFV	7/14/1997	5-10	Calm Seas	- No stability work required or performed
9	Cap Rouge II	M02W0147	47.3	14.7	48.23	NA	SFV	8/13/2002	17	1-1.5	- Not required to submit stability data but inclincing tests were performed in 1974 and, following modifications, in 1987.
10	Hope Bay	M04W0034	126	22.1	72.51	NA	SFV	2/26/2004	16-21	2	- Not required to submit stability data, but a stability report was approved in 1982 which stated that the vessel mus tnot have more than 5 Te of water ballast under fully loaded conditions to ensure sufficient freeboard
11	Prospect Point	M04W0225	70.2	18.29	60.01	NA	SFV	10/29/2004	10	N/A	- Not required to submit stability data but stabiility data was submitted and approved following construction of the vessel in 1978. - The vessel was lengthened in 1986 and a revised stability book was submitted. Thisr report noted errors found in the original stability book regarding the location of the COG and draft. TC requested that additional work be performed for "worst operating conditions" with updated parameters. However, there is no record that these calculations were ever performed or submitted. - The revised stability booklet was never used by the vessel. It was stamped and returned to the naval architect. At the time of capsizie, the original stability booklet was still being used. It was invalid at that time.
12	Ocean Tor	M05W0141	99.7	23.16	75.98	N/A	Fishing Vessel	7/26/2005	20-25	2	- In 1982, an inclining experiment was performed and two stability books were submitted: one for herring packer and one for bottom dragging. The latter was not a requirement and only stamped "noted". The former was approved. '- Modifications were made in 1990. A naval architect estimated new loading conditions in order for the vessel to meet stability requirements. A inclining experiment was supposed to be performed following modifications but there is no record of this occuring.
13	Sea Urchin	M07N0117	<15	10.64	34.91	N/A	SFV	4/11/2007	35	1	- No stability work required or performed '- Post accident analysis showed that the vessel didn't meet STAB 4 criteria.

14	Love and Anarchy	M08W0189	14.57	10.82	35.50	N/A	SFV	9/4/2008	13	1.5	- No stability work required or performed.
15	Le Marsouin I	M09L0074	24.58	14.57	47.80	N/A	SFV	5/18/2009	10-15	1.5	- No stability work required or performed. - Post accident analysis showed that the vessel did not meet most of the STAB 4 criteria
16	Craig and Justin	M10M0014	14.63	11.72	38.45	N/A	SFV	5/1/2010	N/A	Calm Seas	- No stability work required or performed - Post accident analysis showed that, in the vessel's departure condition, it did not meet STAB 4 equivalent criteria (IMO)
17	Jessie G	M12W0054	14.66	11.7	38.39	N/A	SFV	5/4/2012	N/A	Heavy Seas	- No stability work required or performed.
18	Pacific Siren	M12W0062	14.55	10.58	34.71	N/A	SFV	5/9/2012	14-20	1.2-1.4	- No stability work required or performed.
19	Caledonian	M15P0286	259.92	30.63	100.49	N/A	Fishing Trawler	9/5/2015	15	1	- The vessel was subject to LFVIR. As such, it conducted an inclining experiment and produced a stability booklet in 1976. - Post accident analysis showed that, over the 40 year life of the vessel, the lightship displacement had increased by approximately 18.6%. No additional stability work was performed. Post accident analysis showed that at the time of capsize, the freeboard was severly reduced.
20	Lady Devine	M94W0026	12.9	10.97	35.99	N/A	SFV	4/14/1994	25-30	1	- No stability work required or performed.
21	Courageous	M95W0025	44	17	55.77	N/A	SFV	6/20/1995	20-30	N/A	- No stability work required or performed.
22	Dalewood Provider	M95W0222	39	15.22	49.93	N/A	SFV	12/10/1995	38	"High"	- An stabilty booklet was submitted and approved. However, modifications were made and not accounted for, which yielded the stability booklet inaccurate. - The modifications put the vessel's intact stability below STAB 4 requirments.
23	Stephane P II	M96L0037	9.89	7	22.97	N/A	SFV	4/27/1996	"Calm"	0.6	- No stability work required or performed.
24	Inskip	M95W0121	34.7	16	52.49	N/A	SFV	8/29/1995	N/A	"Clear and Calm Seas"	- No stability work required or performed.
25	3J'S '93 (THE)	M96M0128	14	11.58	37.99	N/A	SFV	9/23/1996	20-25	"Rough and Confused Seas"	- No stability work required or performed.
26	CFV 151816	M97N0067	N/A	8.6	28.22	2.6	SFV	01/15/1997	20-25	2-3	- No stability work required or performed.
27	C19496NB	M16A0140	2.7	7.1	23.29	2.44	SFV (Open Speedboad)	6/16/2016	N/A	0.5	- There is no mention in the report of any stability assessments being performed. Based on TC regulations, the vessel was not required to have any stability work performed.
28	Five Star	M14P0121	6	8.69	28.51	N/A	SFV	6/12/2014	28	N/A	- No stability work required or performed.

29	Le Bout de Ligne	M90L3033	58.8	16.8	55.12	5.59	SFV	12/13/1990	35	3.5-4.5	- No stability work required or performed.
30	Sea Serpent 25	M14A0289	5	7.62	25.00	N/A	SFV	6/26/2014	5-10	0.5	- No stability work required or performed.
31	CFV #132145	M93N0001	1	5.5	18.04	1.82	Wooden Open Fishing Boat	7/5/1993	10-15	1	- No stability work required or performed.
32	Sea Gypsey	M09N0031	63	13.91	45.64	N/A	SFV	9/12/2009	20-25	3	- An inclining test was performed and a stability book produced in 2008. However, calculations used a length of 50 feet, not 54. The vessel had been modified in 2002 by adding a four foot extension to the stern. The discrpency was spotted and the book was being reporduced at the time of the accident.
Ireland											
33	Carraig An Isac	MCIB/197	N/A	6.22	20.41	2.56	SFV	1/20/2011	8.1-10.8	3	- No information in report on stability work. However, Ireland's Department of Tourism, Transportation, and Sport requires all vessels less than 15m in length to undergo a roll test to determine the GM
34	Catherine L	No Number	N/A	5.96	19.55	1.9	SFV (Open Punt)	7/18/2005	16.7-27	2.4-3.8	- No information in report on stability work. See note above on stability requirements.
35	Honeydew II	MCIB/135	166	22.7	74.48	7.32	Fishing Vessel	1/11/2007	48.1-54.0	8-18	- The vessel did not have a stability book.
36	Kyle Mhor	MCIB/29	15.96	9.94	32.61	4.24	SFV	10/31/2000	21.6-27.0	"Rough"	- No information in report on stability work. See note above on stability requirements.
37	Dinsih	MCIB/125	379	35.5	116.47	8.1	Fishing Vessel (Stern Trawler)	5/24/2006	10.8-21.6	"Moderate to Rough"	- A satbility book was on board at the time of the incident and "it showed compliance with the stability criteria of the Torremolinos Protocol in a sufficient number of load conditions to cover the work cycle of the vessel and that there was sufficient information to allow the Skipper to maintain adequate stability. This was sufficient to comply with the Safety, Health and Welfare at Work (Fishing Vessels) Regulations, 1999." - One of the conditions of the stability book states maximum drafts that correspond to a negative freeboard. In these conditions, the newly installed fish chute would be underwater. The fish chute failed and allowed an ingress of water
38	Rising Sun	MCIB/118	5.64	8.29	27.20	3.41	SFV	11/29/2005	10.8-21.6	"Slight to Moderate"	- "Marginally" passed a roll test in 2004
USA											
39	Katami	NTSB/MAB-11/03	148	22.3	73.16	7.9	Fishing Vessel	10/21/2008	69.5	7.62	- Modifications were made in 1995. Following these, an inclining test was performed and a stability report issued. An updated stability report was issued in 1998 following further modifications. For vessels less than 79 feet, reports are not required to be submitted for approval. Following the incident, the reports were analyzed and found that they did not meet multiple loading conditions for intact and damaged when compared to requirments for vessels greater than 79 feet in length
40	Advantage	NTSB/MAB/14-16	73	17.5	57.41	6.3	Fishing Vessel	31/09/2012	"Light"	1-1.2	- Vessel not required to have a stability book but one was issued in 1988 and was on board the vessel. The loading suggests that operators were following the guidence of the stability book. However, the stability book was never updated to reflect modifications to the vessel.
41	Christopher's Joy	NTSB/MAB-15/09	120	22.8	74.80	7	Fishing Vessel	9/23/2014	25	1.5-2.7	- No stability work done (i.e. it was an "uninspected" vessel)
42	Hawaii Five-1	NTSB/MAB-16/07	114	21.6	70.87	6.7	Fishing Vessel	11/25/2015	25	2.1-2.7	- No stability work done (i.e. it was an "uninspected" vessel) - Sea trials were conducted in calm to assess intital stability by "feel" of the vessel - Prior to capsizing, the captain noted the slow roll period. Suggests poor stability characteristics
43	Lydia and Maya	NTSB/MAB-17/17	104	21.8	71.52	6.2	Fishing Vessel	9/17/2016	27	1.2-2.4	- No stability work performed.
44	Evanick	NTSB/MAB-98/02	36	15.2	49.87	N/A	Fishing Vessel	4/25/1998	30	3.7-4.9	- Report does not mention stability work. None was required and likely none performed
45	FV Lady Mary	NTSB/MAB-11/01	105	23.1	75.79	6.5	Fishing Vessel	3/24/2009	35	3.7	- The vessel did not capsize, it strictly sank. Therefore, the stability characteristics are not discussed in great detail. The events that led to the flooding, however, are the same as those for many capsizing events.
Norway											
46	Viking 7	Marine 26/10	0.85	6.85	22.47	N/A	Recreational Craft	7/6/2014	13.6-15.5	1.2-1.5	- The *Viking 7* was a recreational craft used for tourism purposes. There was no mention of stabiltiy work performed on the vessel.

47	Marina	Sjø [Marine] 2009/05	N/A	9.12	29.92	2.64	Recreational Craft (but given designation for commercial fishing by authorities)	3/2/2009	"Occasionaly Strong"	1.5-2	- As this was a recreational craft given designation for commercial fishing, there were very little requirments to adhere to. Post accident analysis showed that stability requirements did meet requirements outlined in the Nordic Boat Standard
48	Monica IV	Sjø [Marine] 2011/02	N/A	9.63	31.59	3.06	SFV	9/8/2009	"Gale force"	2-2.5	- No inclinging test conducted. Manufacturer's technical documentation estimated initial stbaility based on a lightship displacement and hull geometry that was incorrect.
Australia											
49	Tamara	Marine Safety Investigation Report No. 185	N/A	12.4	40.68	4	SFV	9/14/2002	20-24	4-6	- No information on stability work performed.
United Kingdom											
50	FV Sally Jane SM74	N/A	18.06	13.6	44.62	4.86	SFV	7/27/1998	4-6	"Calm"	- No stability work performed or required
51	FV Sally Jane SM74	MAIB No. 21/2014	18.06	13.6	44.62	4.86	SFV	9/17/2013	17-21	"Moderate"	- After capsizing in 1998, the vessel was salvaged and the owner produced a full stability book. Vessel met stability criteria.
52	Bounty	MAIB No. 02/2006	10	9.8	32.15	N/A	SFV	5/23/2005	7-10	"Moderate"	- No stability work required or performed.
53	Fraoch Ban	N/A	23.66	15.12	49.61	5.67	SFV	8/15/1999	4-6	"Slight Swell"	- Stability book was approved for the vessel.
54	Angela	MAIB No. 14/2001	27.66	16.99	55.74	6.1	SFV	2/6/2001	17-21	2	- Stability book was approved for the vessel.
55	Kairos	MAIB No. 05/2016	163	18.6	61.02	N/A	Fishing Vessel (trawler)	5/18/2015	30	4	- Stability book was approved for the vessel.
56	FV Harvest Hope	MAIB No. 21/2006	356	28	91.86	8.7	Fishing Vessel (trawler)	8/28/2005	35	3	- Stability book was approved for the vessel.
57	FV Flamingo	MAIB No. 15/2003	82	23.12	75.85	N/A	Fishing Vessel (trawler)	7/7/2002	11-16	1	- No mention of stability work performed in the report. For a vessl of that size, it is likely that stability work would have been mandatory.
58	FV Sundance	MAIB No. 22/2002	3.21	9.07	29.76	3.2	SFV	9/10/2001	11-16	N/A	- No stability work performed or required.
59	FV Stella Maris	MAIB No. 20/2015	12.08	9.96	32.68	N/A	SFV	7/28/2014	"Light air"	"Calm seas"	- No stability work performed or required. - Post accident analysis showed that the vessel had poor stability characteristics compared to vessels greater than 15m in length which are required to have stability work approved.
60	Majestic	N/A	218.27	22.86	75.00	6.4	Fishing Vessel (trawler)	6/13/1989	11-16	2-3	- Stability work was approved for the vessel.

Table 26: Capsizing Incident Reports: Vessel Details

Appendix B-2: Capsizing Incident Report's Contributing Causes

	Canada	Canada			
	Vessel	Causes			
No	Vessel Name	Operators' Practice	Unsafe Modification	Poor Design	Lack of Maintenance
1	Ryan's Commander	- ART tanks were not drained. When initial list occurred due to wind and waves, slack water in tank gravitated to port side, worsening the list. - Fishing gear (trawl net) was on upper deck instead of being stored lower in vessel. Increased VCG		- ART was located above main deck, increasing the VCG - Freeing ports were welded shut and the shipped water on deck could not be drained.	
2	Lannie & Sisters II	- Operators were aware of leak in stuffing box but continued operations		- No high level bilge alarm to alert crew of ingress of water - Batteries located in lower decks of vessel where they would be quickly submerged by water and rendered useless - Freeing ports had no flaps to prevent ingress of water	- Vessel took on water through leak in stuffing box - 5 of 6 bilge pumps not working - Propeller blades damaged. Vibrations due to damage likely increased leak into stuffing box
3	Melina & Keith II	- Vessel had an inherent list but operators continued operations. The righting energy was reduced on the heeled side.	- Over the lifetime of the vessel, many modifications were made that increased the displacement and VCG of the vessel. These modifications reduced stability and freeboard. This included adding A-Frame and winches on main deck	- Freeing ports were welded shut and shipped water could not drain	
4	Big Sister	- Scuppers were plugged which prevented drainage of ingressed water. - The weight and height of loaded lobster traps were loaded such that the VCG increased and the freeboard was reduced.		- No high level bilge alarm to alert crew of ingress of water	- Non watertight hatches which led to an ingress of water
5	Cape Fin-Tose	- The stability books stated that during seining operations, the lazarette fuel tanks were to be empty and trawling gear to be removed from the vessel. This practice was not followed. Tanks were 80% full and trawling gear was on board. - The heeling moment created by seining operations combined with the loading of the vessel led to capsizing			
6	L' Acadien II	- Vessel not constructed for ice but was operating in first year ice conditions - Damaged steering system and had to be towed out - During tow, clutch was engaged and engine was running. This caused the vessel to sheer to port where it hit and was propelled onto ice. While on the ice, the vessel capsized.			
7	Strait's Pride II	- Despite numerous warnings of harsh weather, operator did not seek shelter and continued to fish. - Storm conditions resulted in the port paravane being lost, creatoing a large starboard heel - Storm conditions also resulted in shipped water		- Fish pen design allowed for transverse movement of fish when full. This added to the vessl's heel - The staboard paravane was not able to be released when the portside paravane was lost	
8	Miss Cat Harbour	- Semi permenant ballast was removed from the vessel follwing a transom extension. This increased the COG - Timber which was supposed to be stored in the fish hold was moved to the deck. This loading further increased the COG - The high COG was increased further due to tanks being full above the wheel house - Roll reduction gear was not deployed - Hatches were left open and unsecured which led to unrestricted downflooding			
9	Cap Rouge II	- Tanks and fish holds were all partically full. This condition added to the free surface effect from the downflooding	- Since the 1987 stability test, gear was added that increased the displacement of the vessel. This reduced the inherent stability and made the vessel more susceptible to capsizing		- Ineffective gaskets resulted in the vessel not being sufficiently watertight. Led to downflooding that introduced the free surface effect.
10	Hope Bay	- Vessel was likely loaded not in accordance to the stability booklet. Insufficient freeboard would have made the vessel sucseptible to shipped water from waves led to the free surface effect			- Leaking manhole covers likely led to flooding of holds from water on deck. This would have reduced the vessel's righting energy
11	Prospect Point	- The operators' were seining for sardines at the time of capsizing. This fishery was relatively new to the area at the time of capsizing. When trapped in the seine, sardines will dive towards the bottom, creating a heeling moment on the vessel. It is not clear if the operators were aware of the risks posed by sardine seining at the time of capsizing.	- In 1994 the owner replaced the original cargo boom with a heavier model. - The seine was enlarged. - The steel winch was replaced with an aluminum winch. - None of these modifications were captured by an updated stability booklet.		
12	Ocean Tor	- Crew members noticed that the vessel seemed to be sitting lower than usual in the water. This suggested that there was likely a leak but operations continued anyway.			- A leak in the shaft tunnel resulted in the flooidng of the engine room which reduced reserve buoyancy and freeboard.
13	Sea Urchin	- The seine net was not secured which increased and slid to the starboard side of the vessel. This worsened the rolling due to environmental forces. '- Not all doors were watertight which allowed an ingress of water. This worsened the heel of the vessel			
14	Love and Anarchy	- The operator loaded the vessel in such a way that reduced the vessel's stability. This included additional fishing gear and approximately 800 kg of fish on deck.	- The owners made several modifications that increased the vessel's COG. Refer to the report for the full list. This reduced the vessel's ability to right itself.	- The vessel had a permenant portside list. The cause of the list was unknown.	- Water shipped on deck entered fish holds through hatches that were not watertight. This led to the free surface effect and further reduced the vessel's stability.
15	Le Marsouin I	- Vessel left with an inherent starboard list which was known to the crew. This reduced the vessel's ability to right itself on the starboard side. - Tanks were left partially filled which made the vessel susceptible to the free surface effect. - Lack of permenant ballast reduced the initial stability of the vessel			
16	Craig and Justin	- The loading of the vessel made is more susceptible to capsizing. 275 lobster traps were loaded on the deck, when post accident analysis showed that beyond 171 traps, the vessel would not meet STAB 4 criteria. The freeboard was reduced and the height of the COG increased. - 5 aft freeing ports were blocked off which prevented the drainage of shipped water			
17	Jessie G	- Dangerous loading. Approximately 5 Te of gear stored above the vessel's original COG, this increasing the COG. This reduced the stability of the vessel.	- Numerous modifications were performed over the life of the vessel which reduced it's freeboard.		
18	Pacific Siren	- Loading of the vessel reduced stability. Due to storage constraints, numerous items were stored on top of the deck house. This increased the COG and reduced stability - Paravane stabalizers were used to reduce vessel motions. However, the master was not aware of the effect paravane stabalizers have on vessel stability. They increase the COG and reduce stability.	- Modifications were made that changed the COG of the vessel . While the gross tonnage remained approximately the same, the modifications likely had an impact on the vessel's stability.		
19	Caledonian	- Vessel was not loaded in agreement with the stability book. Loading of the fuel and fish/seawater tanks increased the COG and displacement listed in the stability book. This reduced stabilty	- The vessel displacement gradually increased over the life of the vessel. This reduced the freeboard and reduced freeboard and rendered the previous stability work inapplicable.		
20	Lady Devine	- Owner loaded the vessel havily with prawn traps. The increased COG led to a reduction in stability and freeboard was also reduced. A slow roll period was observed which points to marginal righting energy. - A watertight door was left open which led to flooding. - There was a smalll vessel warning in effect at the time of capsizing but the owner continued operations			
21	Courageous	- Vessel was loaded with heavy equipment stored high on the vessel. This increased the COG and reduced stability. - Vessel operated with seawater in the holds that was supposed to have been drained prior to departure. The implications of the free surface effect were not understood by the crew and stability was further reduced.			
22	Dalewood Provider	- Vessel removed fishing gear and was transporting timber. This loading condition was not accounted for in the stability booklet.	- Modifications were made to the vessel in 1990 that were supposed to include an increase the the breadth. Stability data was submitted and approved based on this breadth increase. However, the final modifications did not include the breadth increase, yielding submitted stability book inaccurate.		- Water entered the hull through an unknown leak
23	Stephane P II	- Lobster traps loaded on the deck that increased the COG, reducing stability. Post analysis showed that in the loading ocndition, it did not meet STAB 4 criteria in multiple categories. - Empty fish hold worsened loading's effect on stability			

	Canada	Canada			
	Vessel	Causes			
No	Vessel Name	Operators' Practice	Unsafe Modification	Poor Design	Lack of Maintenance
24	Inskip	- Operated with "champagne" present in the fish hold. None of the crew knew the impact the free surface effect has on a vessl's stability. - Operations involved lifting a heavy load which caused a heeling moment and raised the center of gravity. - Unsecured loads of fish slid as the vessel rolled to port, worsening the angle of heel.			
25	3J'S '93 (THE)	- The operator continued to fish in deteriorating weather conditions instead of heading to port. In the conditions, the operator chose to travel to rougher shallow waters rather than calmer deep water. - Fish pans were left unsercured which worsened the angle of heel.		- Lack of freeports and the small size of scuppers did not allow for the shipped water on deck to drain.	
26	CFV 151816	- Vessel was overloaded with lobster traps that severely reduced freeboard. - The lobster traps were loaded in a way that increased the COG and reduced the vessel's stability.			
27	C19496NB	- While hauling up a third line of lobster traps, the line became tangled with the other lines and it pulled the vessel downward. This reduced the freeboard and eventually led to shipped water. Decision to cut the line was made too late.			
28	Five Star	- A large catch of crab was loaded on the vessel's working deck, increasing the COG and reducing stability - Water was added to the tore, further increasing the COG - Vessel left port with inherent list - Captain made decision to continue fishing in harsh conditions	- Stern extension added and effects on stability not assessed.		
29	Le Bout de Ligne	- The decision to continue fishing in harsh conditions made the vessel susceptible to capsizing. This was due to ice accretion which increased the COG of the vessel and reduced stability. The vessel was also travelling in following seas which likely led to broaching in large waves, again making the vessel more susceptible to capsize.	- A fish box and stabalizers were added to the vessel without any assessment of the impact on the vessel's stability.	- Fish box allowed for an ingress of seawater without effective drainage. This would have increased the COG and introduced the free surface effect.	
30	Sea Serpent 25	- A drain plug was either not reinserted or not reinserted correctly into a drain hole and an ingress of water occurred.		- The vessel had no bilge pumps to remove shipped water.	
31	CFV #132145	- There was an unequal distribution of weight when 2 of the 3 members of the crew moved to the lee side of the vessel and a list was created. When a large wave hit the vessel it was not able toright itself and it capsized			
32	Sea Gypsey	- Lazarette cover not secured. This would have resulted in shipped water flooding the lazarette.			
	Ireland	Ireland			
33	Carraig An Isac	- Vessel may have been overloaded which reduced its stability			
34	Catherine L	- Vessel was operating in very harsh conditions that likely led to swamping and capsizing. The report states "the weather conditions at the time were more than a match for the 18-foot open punt".			
35	Honeydew II	- It is likely that watertight hatches and doors weren't shut. This resulted in an ingress of shipped water in rough conditions			
36	Kyle Mhor	- The vessel was ballasted with loose materials that likely shifted as the vesel rolled. This improper loading would have increased the list. - The cover the the fish has was foam that may have floated off with shipped water. This would have lef to an ingress of water and flooding.			
37	Dinsih		- The vessel underwent modifications and extensive repairs in May, 2006. This included a fish chute. The modifications were not accounted for with a survey to ensure previous stability work was still valid. In certain conditions the fish chute would be underwater and failure of the fish chute would lead to flooding.		- Condition of the fish chute was not monitored and its deterioration was not noted.
38	Rising Sun	- The vessel was heavily loaded at the time of capsize which reduced the vessel's freeboard. As this was primarily attributed to gear on deck, the COG was increased which reduced the vessel's stability.	- Following the roll test in 2004, various pieces of heavy equipment were installed that increased the COG of the vessel and reduced the freeboard. This had a negative effect on the vessel's stability.		
	USA	USA			
39	Katami	- Operator chose to operate in harsh weather conditions despite numerous warnings. Most other vessels in the area sought shelter. - The vessel was overloaded with approximately twice the frozen cargo as outlined in the stability report (120,000 lbs vs 60,000 lbs). This severely reduced freeboard. - Watertight doors were left open which allowed for flooding	- Stability report did not account for changes as the vessel was modified after 1998 from a shrimp trawler to fish for cod.	- Area of freeing ports were much smaller than those required by vessels greater than 79 feet (1.6 ft^2 vs 10 ft^2). This allowed for shipped water to accumulate on the deck.	
40	Advantage		- Numerous changes were made throughout the life of the vessel and the stability book was never updated.		
41	Christopher's Joy	- The fishing gear deployed during opertions had the effect of increasing the COG of the vessel. Operator was not aware of the effect that this had on the stability of the vessel. When turning, the vessel could not overcome the heeling moment created by the rudder and capsized.	- Owner made multiple modifications to the vessel without any assessment from a naval architect		
42	Hawaii Five-1	- Heavy equipment and steel plates were stored above accomodation spaces which increased the COG of the vessel and reduces stability - Captain was aware of poor stability but did not take actions to remedy situation such as weathervaning or reducing speed - Watertight door was left open which led to an ingress of water		- Deckhouse was assymetrical which prevented proper drainage of shipped water	
43	Lydia and Maya	- Crew blocked freeing pors with steel plates which prevented the drainage of shipped water - Heavy cargo and gear was stored on upper decks, increasing COG and reducing stability - COG was further increased because of a suspended load of ~7000lbs. Vessel transited with suspended load. The boom carrying the load broke and the load fell to the deck. Load should have been lowered deck before moving. - Vessel had an initial heel that was likely due to shifting cargo			
44	Evanick	- 5000 lb skiff was stored on aft deck, increasing the vessel COG and reducing stability			
45	FV Lady Mary	- The lazarette cover was found to be off. This would have led to flooding from shipped water	- Modifications were made that increased the vessel's weight by approximately 5%. This reduced the vessel's freeboard and made it more susceptible to flooding.		
	Norway	Norway			
46	Viking 7	- Vessel was overloaded beyond the manufacturer's specificiation. Reduced freeboard that led to an ingress of water		-"accident occurred as a result of lack of compliance with recognised design standards for recreational craft." - ISO 12217-1:2013 specifies the minimum freeboard to the waterline of downflooding openings. The Viking 7 did not meet these requirements	
47	Marina	- Poorly loaded. The fish hold was full so an additional 900 kg of fish were loaded (unsecured) on deck. This would have reduced the free board and inherent stability of the vessel as the height of the COG was increased. The shifting of the unsecrued load on deck led to a large angle of heel that the vessel could not recover from.			
48	Monica IV	- Vessel was rigged with heavier fishing gear than designed to support. This would have increased the COG and reduced stability		- Small freeing ports did not allow for sufficient drainage of shipped water. 20% of Nordic Boat Standrard requirements	
	Australia	Australia			
49	Tamara		- Modifications also included the addition of three ice boxes on the working deck. This would have raised the COG and reduced stability	- Watertight bulkheads were penetrated. Led to multiple compartments flooding instead of just one. - Freeing ports welded shut.	

	Canada	Canada			
	Vessel	Causes			
No	Vessel Name	Operators' Practice	Unsafe Modification	Poor Design	Lack of Maintenance
United Kingdom		United Kingdom			
50	FV Sally Jane SM74	- While quay side, the vessel was lifting fishing gear. 2 sets of gear each weight approx. 1.8 Te were lifterd 8.5 m above the deck. This effectively raised the COG of the vessel and reduced stability. - Vessel was low on fuel, fresh water, and ice. Because the holds lower in the vessel would have been close to empty, the height of the COG would have been further reduced	- There were minor modifications made to the vessel with no considerations to the vessel's stability.		
51	FV Sally Jane SM74	- Uneven loads in the port and starboard trawl nets resulted in a significant heeling moment. Likely due to load in starboard net being released. Operator was unable to release contents from the port net. - Derrick was raised while turning. This increased heeling moment on the vessel. Stability significantly reduced - Watertight hatches and doors were left open which resulted in flooding after the vessel heeled. - Operators did not follow stability books. Aft tanks were routinely full instead of at 50% as required by stability books. Reduced freeboard.		- Length of derricks resulted in significant heeling moment. Smaller derricks with a shorter moment arm would have produced a smaller heeling moment under assymetrical loading	
52	Bounty	- While trawling, the trawl snagged the seabed and the vessel became stuck. - Vessel was loaded such that it had very little freeboard.This resulted in the vessel becoming swamped when it was hit by a wave. Led to list and eventual capsize.		- Freeing ports' size was insufficient to clear shipped water. The area was less than recommended	
53	Fraoch Ban	- While fishing for eel, a large list occurred and the vessel capsized. The stability book did not account for eels. - Pen boards were not installed correctly. Gaps allowed the laod to shift in the holds. - Eels in the holds introduced the free surface effect and reduced stability. Pen board arrangement was not sufficient to reduced FSE.			
54	Angela	- While crew were gutting fish, the vessel listed to starboard and began to flood. Led to capsize. - Fish boxes were stored on deck when they should have been stored in the hold. Increased the COG and reduced stability. Not in compliance with stbaility book. - The vessel had a full hopper on deck which further increased the COG and reduced stability.			- Bilge alarms did not sound to alert the crew of flooding. - Tonnage valves (similar to freeing ports) were not working properly and did not allow the vessel to rid itself of shipped water.
55	Kairos	- Vessel capsized when trying to recover a lost trawl. Resulted in wire load on the winch that heeled the vessel. - Trying to recover the trawl in harsh weather led to shipped water.		- Downflooding occurred through an air vent.	
56	FV Harvest Hope	- Trawl gear became snagged in a pipeline on the seabed - Tension on the line caused the vessel to heel. Port transom door was left open which allowed for flooding. - A cabin window was also left open. Flooding increased as water entered through this window when the heel increased.	- Additional ballast was added for stability purposes. However, this reduced the freeboard lower than the original design.	- Freeing ports were welded shut. - Unable to close transom door once there was shipped water. Made it impossible to cease the ingress of water	
57	FV Flamingo	- While trawling, the weaklink on the port side net broke. Caused a heeling moment starboard on the vessel. - Auto piot was left on while trawling which would have worsened the heel. - When water was taken on, watertight doors were not shut which resulted in flooding. - Arrangment of derricks during cleaning raised the COG.	- Derrick lengths were increased which raised the COG and reduced stability. Modifications were not known to authorities.		
58	FV Sundance	- Crew were trawling and snagged a load that was too large for the winch to handle. When they trie to lower back to the seabed, it bacame caught in the stern and would not lower. The load caused the vessel to heel and it eventually became swamped. - Skipper continued to try and lift the load although it was abnormally heavy. It should been released instead of trying to haul it to the deck.		- Lifting arrangment usually resulted in a starboard list. Arrangement also reulted in a very high COG when hauling in loads - Freeing ports were found to be smaller than recommended.	
59	FV Stella Maris	- While trawling, the crew caught a heavy load. As they attempted to lift the load on deck, they realized it was too heavy as it caused the vessel to list. They attempted to lower it back to the seabed but the load because caught on the stern. As the list continued, the freeports became submerges and flooding occured. - Given the weight in the net, the owner should have recognized the risk posed by attempting to lift the load aboard. Should have lowered the load to the seabed before trying to recover it. - Gear was regularly stored on the wheelhouse. Increased the COG and reduced stability.	- Modifications were made to the vessel which involved replacing equipment with lighter parts. Because the new equipment was lighter, it was assumed that stability characteristics were improved. However, the height of the equipment was not considered. - The new A-Frame was higher than the older one. With a higher lifting point, the heeling moment that arose from lifting a catch on deck was increased.	- Freeing ports should have been placed higher in the bulwark. This may have prevented flooding as it would have taken a larger angle of heel for flooding to occur. - Location of fish hopper increased the COG of the vessel	
60	Majestic	- Vessel was trawling when net became snagged in the seabed. The tension on the line was assymetrical and cauased the vessel to heel. Flooding occurred through doors that were left open. - Due to loading, the vessel had a 7° list prior to the incident. - Vessel's watertight integrity was comprimised because doors on the shelter deck were left open during operations.			

Table 27: Capsizing Incident Reports: Contributing Causes

Appendix C: Detailed Roundtable Results

Roundtable 1

1. What does it mean to have a stable vessel?

When posed this question, all participants agreed that the roll motion of a vessel is one of the most important indicators of a vessel's stability. Participants recognized that a tender vessel with a slow roll period is more susceptible to capsizing than a stiff vessel that would be considered uncomfortable. They were aware that comfort and stability are at a cost to each other. The importance of ensuring no initial list and that the vessel is "upright" was brought up. If there is an inherent list, a vessel's stability is likely in jeopardy. Finally, all participants agreed that it is difficult to assess a vessel's stability with no experience aboard that vessel. It is important to be familiar with the vessel before commencing operations, and stability should not be simply assumed based on prior naval architecture or engineering work.

2. Do you have a stability book? Do you think they are useful?

Opinions on this topic were much more divided. Some members felt that stability books served little to no purpose. Participant 1 stated that he "never had a stability book" and "I don't think it has a positive effect." Some participants also stated that they did not know how to use or read a stability book. Participant 3, however, expressed that he felt stability work was important. He stated that he knew how to use his stability book and felt it was beneficial. Further, he felt that the inclining test was a good indicator of stability and that he "wouldn't think about going out without a stability test."

While opinions varied on the importance of stability books in maintaining a stable vessel, there was agreement that operator experience and best practices are imperative;

stability work by naval architects and engineers on its own is not enough to ensure a stable vessel. There was consensus that operators' best practices are achievable without a stability book.

3. How do you maintain the stability of your vessel?

Answers to this question were varied, but there was no disagreement from a participant regarding another participant's answer. Answers included:

- Ensure the vessel is watertight
- Avoid shifting loads (both on deck and in the hold)
- Know the weather conditions and take precautions as necessary
- Have experience on the vessel

The final point regarding experience is an important consideration for this study and this was another point in which there was agreement amongst all participants. In order to maintain stability of a particular vessel, it is important to have experience on that vessel and know how it behaves. This point resonates with what was brought up with stability books: operator practice and experience plays a significant role in vessel stability.

4. What poses the largest risk to the stability of your vessel?

The most common answer to this question was the species being caught. It was stressed that species that act as a free surface in the hold of a vessel pose the largest risk to capsizing that vessel. In the Newfoundland and Labrador fishery, these species are predominantly mackerel and herring. The "low viscosity" of these species in bulk results in the load shifting in the hold and makes a vessel more susceptible to capsizing. The group also spent considerable time discussing the risk that sea cucumbers pose to operators. Participants explained that sea cucumbers have the ability to change shape. This characteristic allows the species to escape their hold through any small holes or openings in pen boards, thus creating a shifting load. Further, sea cucumbers can plug pumps, which hinder an operator's ability to rid the vessel of shipped water. Sea cucumber is a relatively new fishery in Newfoundland and Labrador, and the group felt that it would likely cause problems as more operators begin to partake.

Shifting loads was brought up once again by the group. For the catch in holds, it was agreed that the pen boards are the most important means of preventing shifting loads. On the vessel deck, strapping down any equipment was stated as the most important measure to take. These extra considerations were considered an important part of preventing shifting loads to avoid capsizing.

Finally, it was agreed by all participants of the roundtable that down-flooding posed a significant risk of capsizing because of the free surface effect. All participants understood that the free surface effect reduced a vessel's stability. It was agreed that the most likely causes of down-flooding for a fishing vessel are operating in harsh weather and a lack of maintenance. Operating in harsh weather can lead to shipped water. If the vessel is unable to rid itself of the shipped water, it can find its way into the holds and introduce the free surface effect to the vessel. If vessels are not maintained, their watertight integrity may become compromised. This often results in leaks and flooding. In many instances, a combination of operating in bad weather with a poorly maintained vessel can lead to down-flooding. On the topic of harsh weather, a participant mentioned that many operators are willing to fish in rough conditions, so it is important that operators know how to handle their vessel.

5. What are the most effective ways to reduce capsizing?

All participants of the group agreed that the most effective way to reduce capsizing was improved education and awareness among fishing vessel operators. Ensuring that operators understand the effects of changing a vessel's center of gravity and that of a free surface were brought up as two important aspects. Formal stability training was mentioned as being important, but there is a need for both formal training and experience. The importance of stability education was summarized by a Participant 3: "Education awareness allows you to take a calculated risk as opposed to a blind risk."

A participant suggested that additional educational programs be offered by the NLFHSA. This speaks to the recognition amongst the group that education is important. However, participants felt that any voluntary programs offered should not replace the current formal training required by certain operators, but instead supplement it. It was also brought up that individuals must be motivated to pursue additional training if it is not required by any regulations.

Roundtable 2

1. What does it mean to have a stable vessel?

Participants cited the “feel” of a vessel as the primary indicator of that vessel’s stability. When pressed on how a stable vessel would feel compared to an unstable vessel, a participant said that unstable vessels tend to be “more sluggish” and do not answer properly. Loading was also discussed and it was pointed out that excessive top weight can lead to an unstable vessel. As the discussion progressed, experience was brought up. Members agreed that it was not possible to determine a vessel’s stability strictly by its “feel” - the operator must have extensive experience on the vessel and know how it behaves. Expanding on that point, the consensus amongst the group was that it would not be possible to step aboard a new vessel and assess its stability by how it “felt.”

Participant 6, who operated a 34’11” vessel, said that a previous vessel they operated was unstable. When asked why, they replied, “it was always bobbing up and down.” The operator felt that because the vessel was stiff and uncomfortable, it was not stable. When Participant 6 relayed this to the group, they were quickly corrected by another member (Participant 7) who said that the vessel was likely stable because it responded quickly to disturbances. This response was met with general agreement within the group. Upon being corrected, Participant 6 contributed little for the duration of the roundtable.

2. Do you have a stability book? Do you think they are useful?

Two of the seven members of group had stability books (Participants 2 and 3). They felt that the stability books were useful and they provided the operator with confidence. There was little reply from the other participants on stability books. However, a participant pointed out that many of the vessels lost have been equipped with stability books. When posed with the question of whether operators' practices or inherent stability was more important, consensus amongst the group was operators' practices. The group felt that stability analysis by itself is not sufficient to prevent capsizing.

3. How do you maintain the stability of your vessel?

Participants of the group initially mentioned loading as an important consideration for maintaining a vessel's stability. It was well known amongst the group that it was important to avoid top weight and keep loads low. Ensuring that shifting loads are prevented was also mentioned. A participant said that modifications should be considered in order to maintain a stable vessel. On this point, Participant 4 asked whether or not raising the deck of a vessel three feet would have an impact on a vessel's stability. A participant with extensive training and a sound understanding of stability (Participant 2) answered and explained that it would.

In this portion of the roundtable, the type of species was brought up as being an important consideration for maintaining a stable vessel. As was discussed in the first roundtable, a participant said that sea cucumber was the worst species for shifting loads. Seal, capelin, and squid were also mentioned as being problematic for shifting loads.

Finally, experience was mentioned as being an important part of ensuring a vessel's stability. The group agreed that, in general, experienced operators have better practices. Members were in agreement that in today's fishery, operators are more aware of the importance of stability and knowledge is improving in this area. A participant highlighted the need for operator awareness and stressed that everything possible must be done to encourage safe practices and identify possible hazards.

4. What poses the largest risk to the stability of your vessel?

Points brought up in the previous question were mentioned again (height of gear, loading of the vessel, shifting gear/loads, species), but the majority of this question revolved around free surface. Participant 2 stated, “Free surface is the killer.” Participant 2, who as mentioned previously had extensive stability training, contributed the greatest amount to this portion of the discussion. He stated that partially loaded vessels are at the greatest risk of capsizing because there are often problems with dewatering. As a result, the free surface effect becomes a problem and can make a vessel more susceptible to capsizing. The participant stressed that many operators still do not understand the free surface effect and that a free surface is often detrimental to the safe operation of a fishing vessel.

Down-flooding and a lack of maintenance were cited as other significant risks to vessels capsizing. This was considered more dangerous than overloading a vessel by Participant 2 when he stated, “A fully loaded vessel that does not down-flood won’t capsize.” However, it was pointed out that in rough weather, a heavily loaded vessel can lead to a difficult situation because the operator may be unaware he or she is taking on shipped water. This, in turn, can lead to down-flooding.

5. What are the most effective ways to reduce capsizing?

On this point, the group agreed that it was best to focus on implementing best practices to reduce capsizing. Stability books were encouraged by participants who had stated they found them useful earlier in the roundtable. When training was brought up, the general consensus was that most operators would be interested in an awareness program that focused on stability. For operators of smaller vessels, training should be more practical than the formal training currently required by operators of larger SFVs.

Roundtable 3

1. What does it mean to have a stable vessel?

This question was met with initial silence. Upon encouragement from the chair, Participant 4 said that there was a "feeling of safety" on a stable vessel. When asked what he meant, he explained that a vessel that is more comfortable in rough water is more stable. His comment was not corrected by any other members of the group.

The group was asked by the chair how they would describe an unstable vessel to a non-fisherman. Participants 2 and 3 described that the vessel would have high freeboard for a comparatively small draft. This suggests the participants were aware that a high center of gravity reduced stability. When pressed to describe how an unstable vessel would feel, they responded with "tippy." This term may refer to an uncomfortable vessel which would have high initial stability.

Participants mentioned that it is important to tie gear down to avoid shifting loads and that the loading of the vessel affects its stability characteristics. A participant said that the onus is the builder to ensure the vessel is stable. Another participant spoke up and said that he felt the onus is both on the builder and the operator. This second comment was agreed on within the group. It was clear that while the participants felt that vessel design was important, they also recognized the role of operators in ensuring safe operations.

2. Do you have a stability book? Do you find them useful?

No participant had a stability book or had used one before. They offered no opinion on whether they felt they were beneficial or not.

3. How do you maintain the stability of your vessel?

The group was repeatedly prompted for a response to this question. However, no participant offered any input. After multiple attempts, the chair moved on to the next question.

4. What poses the largest risk to the stability of your vessel?

Shifting gear and rough weather and waves were mentioned as two primary risks of vessel stability. Participant 1, who had the least experience, was quick to mention weather. The other participants agreed it was shifting gear. Participant 2 said that common sense was important when considering the risk of a vessel capsizing. He explained that common sense referred to knowing how to handle your vessel in rough weather and knowing how to "manage the waves." In other words, experience is considered important for an operator. This resonates with ideas discussed during the first two roundtables.

5. What are the most effective ways to reduce capsizing?

When posed this question, there was again little response. Based on the group's reluctance to answer, the chair asked if they considered capsizing to be a risk. The consensus was that no, they did not. Participant 2 said, "[I] probably wouldn't go out if I thought like that." This comment was not met with any opposition or disagreement from other members.

One of the incidents analyzed in section 5.1 was the *Miss Cat Harbour*. This vessel capsized in the region and the participants were familiar with the incident. It was brought up at one point during the discussion and led to the most involved conversation of the roundtable. When discussing the incident, Participant 3 blamed the autopilot of the vessel malfunctioning. The TSB report, however, cited operator’s practice as the primary cause of the vessel capsizing.

Members said they would be open to and educational program that focused on stability training. Participant 2 stated that “it wouldn’t hurt none.” When asked about the best way to implement an educational program, consensus was that multiday classroom sessions with an instructor would be best. All members preferred this option to a web based training program that they would complete at their own pace.

Appendix D: Detailed Calculations for Hypothesis Test of Slope of Regression Line

To test for statistical significance, a *null hypothesis* was established which stated the slope of the regression line (b_1) was zero. In other words, the number of capsizes is independent of the year. The *alternative hypothesis* was then established as the slope of the regression line being less than zero. If the probability of the slope of the observed regression line (-0.037) occurring given that the assumed slope is zero is sufficiently small, the null hypothesis is rejected and it can be concluded with confidence that the alternative hypothesis is valid. For this analysis, probability will be considered sufficiently small if it is less than 5%. Hypothesis testing of a single linear regression analysis uses the t - distribution as it makes an inference of a general trend based on a sample's mean and variance (Walpole et al., 2012).

Hypothesis Testing		
H_0	Null Hypothesis	$b_1 = 0$
H_1	Alternative Hypothesis	$b_1 < 0$

Table 28: Hypothesis Testing of the Regression Line Slope

Year	x	y	x*y	x^2	S_{xx}	S_{yy}	S_{xy}
2004	1	4.1	4.1	1.0	42.3	0.7	-5.6
2005	2	3.6	7.2	4.0	30.3	0.1	-2.0
2006	3	4.3	12.8	9.0	20.3	1.0	-4.6
2007	4	2.4	9.7	16.0	12.3	0.7	2.9
2008	5	4.4	22.1	25.0	6.3	1.4	-2.9
2009	6	1.9	11.4	36.0	2.3	1.8	2.0
2010	7	3.3	23.3	49.0	0.3	0.0	0.0
2011	8	1.4	11.0	64.0	0.3	3.5	-0.9
2012	9	2.4	21.8	81.0	2.3	0.7	-1.2
2013	10	3.2	32.4	100.0	6.3	0.0	0.0
2014	11	4.4	47.9	121.0	12.3	1.3	3.9
2015	12	3.2	38.1	144.0	20.3	0.0	-0.3
2016	13	4.5	58.1	169.0	30.3	1.5	6.8
2017	14	2.3	31.6	196.0	42.3	1.0	-6.4
Sum	105	45.3	331.3	1015.0	227.5	13.7	-8.3
x = Independent Variable, y = Dependent Variable							

Table 29: Regression Analysis Calculations

Parameter	Symbol	Value
Average Dependant Variable	y_bar	3.2
Average Independant Variable	x_bar	7.5
Regression Line Slope	b_1	-0.037
Regression Line Intercept	b_0	3.51
Error Sum	S_{SE}	13.35
Variance of Error	s^2	1.11
Standard Deviation of Error	s	1.05
Standard Error	s_{b1}	0.070
Number of Observations	n	14
Degrees of Freerom	DOF	12
t - value	t	-0.52
Probability	p	0.30

Table 30: Regression Analysis and Hypothesis Testing Results

The t – value in Table 30 was calculated by subtracting the null hypothesis' slope from the observed slope and dividing the difference by the standard error.

$$t = \frac{b_1 - 0}{S_{SE}}$$

The probability was then calculated in excel using 12 degrees of freedom[5] and t – value of -0.52 (this can also be obtained by referencing published t – value tables). As per Table 30, the probability that the observed regression slope is due to noise in the sample is 30%. This value is significant and greater than the 5% threshold originally cited. Therefore, the null hypothesis cannot be rejected with confidence

[5] The number of degrees of freedom for a t - distribution is the number of observations minus two (there are two values that can vary in the data set: mean and variance). Since there were 14 years, the degrees of freedom for this analysis was 14 - 2 = 12